Studies on Thysanuran Anatomy. By H. T. Fernald.

(Preliminary Communication.)

The importance of a complete knowledge of the anatomy of the Thysanura for the intelligent consideration of questions relating to insect phylogeny, has led me to devote considerable attention to this group. A more complete paper, of the original portion of which this is but an abstract, is now ready for publication.

The forms here considered are Anurida maritima, and Lepisma saccharina—the former quite fully, the latter only in a few particulars.

In Anurida the two pairs of mouthparts—mandibles and maxillae—can be protruded from, or drawn into the cavity of the head where they lie in a sort of pocket, ventral to the pharynx. The digestive tract is composed of three chief divisions—fore, mid and hind gut—separated from each other by structures functioning as valves. The fore gut has no longitudinal muscles and the circular fibres have all their nuclei on the middle dorsal line of the gut. In the mid gut no chitinous lining is present, but the free surface of the epithelium is covered by fine hairs which constitute the "Härchensaum" described by Frenzel (Arch. f. Mik. Anat., XXVI, p. 229, 1886). In molting, the nuclei of these cells divide, and the products of this division pass to opposite ends of the cells. The cells themselves now divide, and the portions nearest the lumen are set free. These form a mass which lies in the gut till the cuticula of the exterior of the body is thrown off, when it is expelled.

A structure termed by Sommer (Zeits. w. Zool., XLI, p. 683, 1885) the "exkretionsorgane" in Macrotoma, is present in Anurida, and I regard it as homologous with the fat body of the higher insects. Its connection with the hypodermis, Sommer believes, proves that this is not correct, but my specimens appear to indicate that such a relation is only secondary.

The heart lies on the dorsal middle line, and at its anterior end becomes continuous with the aorta, which passes forward and after a time bends ventrally and rests on the fore gut. Farther forward it entirely surrounds this, and extends below it to the sub-œsophageal ganglion. A little anterior to this point it abruptly ends. The nervous system consists of a brain, a sub-œsophageal ganglion and three ventral ganglia, one in each segment of the thorax. No abdominal ganglia occur, but the metathoracic ganglion appears to have resulted from the fusion of at least two.

In each of the main nerve trunks, near its origin, lies a very large nucleus, more than twice the size of the nuclei of nerve cells, nuclei of the ganglia or brain. I have been unable to ascertain its significance. From the brain are innervated the antennæ and eyes; from the sub-œsophageal ganglion, the mouth parts; from the thoracic ganglia, the different parts of the segments in which they are situated; the metathoracic ganglion, in addition innervating the abdomen. One or two small ganglia with two or three nerve cells are present in the more distal joints of the legs. Tactile bristles are scattered over the surface of the body, and are especially abundant in the antennæ and around the mouth.

On the terminal joint of each antenna is a small trilobed organ, similar to the bilobed organ described for Campodea by Kingsley (Am. Nat., XVIII, p. 540, 1884.) I have traced its connection with a nerve fibre, and am inclined to look upon it as in some way aiding in the determination of the forms of the objects which it may touch. There are five eyes on each side of the head, each consisting of a nearly spherical mass of protoplasm containing four nuclei, and covered externally by the cuticula which is here smooth, though bearing small protuberances elsewhere. Immediately beneath the protoplasm is a dense layer of pigment. The different eyes of each side are entirely independent, and lie some little distance apart. No structure resembling an ommatideum could be found.

The post-antennal organ described by Laboulbéne is situated between the eyes and the base of the antenna, on each side of the head. It is a rosette like structure, consisting of from seven to nine ovoid bodies radiating from a centre. At the central end of each is a sort of pedicel or stalk joining the

ovoid portion to the head. Both parts of the organ are filled by a pigmented protoplasm continuous with the hypodermis. No nerve connection was observed.

The abdominal vesicle is situated on the ventral surface of the first abdominal segment. It is cleft longitudinally and the hypodermic cells lining this cleft are glandular in appearance, and are larger than on the outer sides of the vesicle. Passing forward from this point on the ventral middle line of the body to a median cleft in the lower lip, is a small tube, in the formation of which both hypodermis and cuticula take part.

In the posterior portion of the head are a pair of glands which resemble salivary glands and which I regard as their homologues here. From these glands a duct leads forward and soon fuses with its fellow, and the median duct thus formed passes along the under surface of the buccal cavity to a median cleft of the under lip, where, instead of emptying into the mouth, it turns downward and joins the ventral tube just described. This remarkable relation of the parts concerned I am unable to explain, although sure that no error of observation was made. Traces of a rudimentary "spring" occur in the fourth abdominal segment. The female reproductive organs are a pair of tubes, the ducts from which join, forming a median duct with a ventral diverticulum—the receptaculum seminis. The structure of these parts and the formation of ova is nearly the same as described by Sommer (*l. c.*) for Macrotoma.

The number and arrangement of the male reproductive organs is the same as in the female except that there is no ventral diverticulum of the median duct. In both sexes the external opening of this duct is on the fifth abdominal segment.

In the immature testis are groups of granules and scattered nuclei. These groups develop, the granules elongate, and form threads lying in bundles. Soon degeneration occurs, resulting in the formation of a quite homogeneous mass, with scattered nuclei, around which protoplasm collects, forming a sort of epithelium in which fat globules and spermatozoa are formed.

Lepisma saccharina is larger than Anurida, and has ten abdominal segments. Three anal cerci and several abdominal appendages are present, and the female has in addition a long ovipositor.

The mouth parts are of the mandibulate type and cannot be retracted into the head. The digestive tract behind the brain gradually enlarges till near the end of the fourth abdominal segment, where it abruptly contracts, and now in its walls six chitinous rods are formed, armed with stout teeth, while the circular muscle layer becomes much developed. Beyond these rods the lumen becomes still smaller and turns dorsally, then suddenly bends ventrally and enters the stomach. This has extending forward from the entrance of the portion just described, six short cæca. It passes back into the seventh segment of the abdomen, where it makes a half circle to the left, and joins the ileum which completes the circle, passing dorsal to the stomach, and continues back about one segment when it enters the rectum. The rectum is a large irregularly shaped chamber with many folds and diverticula. It finally narrows and leads by a very short straight tube to the anus.

The epithelium of the stomach bears a "Härchensaum," and in many places forms small crypts, the function of which is claimed by Oudemans to be the formation of new cells. The crypts are certainly suggestive of a glandular function, however. The stomach has no chitinous intima, but all the other parts of the digestive tract are lined by a cuticle. This is the case in the ileum, from the anterior end of which several Malpighian tubes are given off. The epithelium of the ileum is thrown into six longitudinal folds. This whole portion is supported by mesentaries passing in various directions, accompanied by muscle fibres. The rectal epithelium is columnar and its cell walls stain very faintly. The nuclei lie near the bases of the cells.

Salivary glands of a simple nature and with no noteworthy features, are present. The fat body is apparently of the same structure as in Anurida.

The heart leads forward into an aorta, which in the prothorax bends downward from the dorsal surface of the body till it touches the œsophagus. It does not enclose this but soon becomes lost. The heart at its posterior end is wide open, somewhat like the mouth of a trumpet, anterior to which point it becomes small, and with very muscular walls. About two abdominal segments farther forward it quite rapidly enlarges till its lumen is seven or eight times as large as it was before, while the walls become thinner. The heart between here and the aorta has its usual structure, with ostia, none of which were observed in the muscular portion.

A tracheal system is present, but I failed to ascertain its exact distribution.

The nervous system consists of a brain, sub-œsophageal ganglion, three thoracic and eight abdominal ganglia. Of these the last thoracic and first two abdominal ganglia, and the seventh and eighth abdominal ganglia are partially fused.

The brain is more complicated than in Anurida, calyces being present. No trace of the large nuclei at the origins of the main nerve trunks, was found.

Each eye consists of twelve facets or ommatidea. Each ommatideum consists of a large cornea, beneath which are two corneagen cells. The crystalline cone has the form of a concavo-convex lens, and just lateral to it are the four cells of the vitrella.

The rhabdomere is pyramidal, its base resting against the internal face of the crystalline cone. Surrounding it are four retinulae which are densely pigmented and the proximal ends of which perforate the basement membrane and become optic nerves. The ommatidea on the whole somewhat resemble those of Serolis. Between them are packed pigment cells.

The position and structure of the reproductive organs of both sexes is much the same as in Anurida.

Lepisma seems to represent about the highest grade of differentiation yet attained by the Cinura, while Anurida seems to have undergone a differentiation perhaps even greater, but followed by a degradation, probably correlated with a change of habits and food. The internal anatomy of the Thysanura as a whole appears to confirm the Campodea theory advanced by Braur.

The

Relationships of Arthropods

A Thesis submitted for the degree of

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by

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Contents.

Introduction.

The problem of the phylogeny of Arthropods has recently [illegible] attention [illegible] researches. [illegible] however, have been upon the Crustacea, Limulus, Peripatus and the Arachnids, nearly all writers contenting themselves with a few statements of the "probabilities" concerning the Hexapods and Myriapods.

The theory of Brauer and Lubbock, that the insects are derived from a Campodea-like ancestor, was in a great measure the result of the discovery that in widely separated groups Campodea-like larvae occur, and the theory was formulated almost entirely from external features. Important for the acceptance or rejection of this belief, therefore, as is the study of the anatomy of larvae and of the Thysanura to which group Campodea belongs, almost nothing in this line has been attempted, and the scattered papers comprising the literature of the subject abound in inaccuracies and erroneous inferences.

The group Thysanura as given by [illegible] really consists of two — the Cinura, including the genera Campodea, Japyx, Machilis, Lepisma &c. — and the Collembola, a larger group, including the genera Smynthurus, Tomocerus, Podura, Lipura &c. To these the [illegible]

been added a third—the Symphypleona—containing the single genus [illegible].

The anatomy of most of the Insecta is now quite well known thanks to the patient and careful labors of Grassi, Lubbock and others but for the anatomy and histology of the Collembola I have been able to find but one recent paper—an article upon "Macrotoma Tomocerus" by Sommer '85.

Our ignorance of these groups and the value of a knowledge of them for the student of the phylogeny of Arthropods has induced me to devote my attention chiefly to these forms. My studies have been upon a degenerate Collembolan, Anurida maritima, and upon the Cinuran Lepisma saccharina. I shall here give the results of [illegible] and consideration of the most prominent views as to the phylogeny [illegible] positions by the light of the studies just preceding. Finally I shall sum up the conclusions reached and offer a few suggestions as to the origin of the group and the possible paths along which its main branches may have developed.

Anatomy of Anurida maritima, Guér.

This little animal occurs along the eastern and western shores of the Atlantic Ocean. It has been reported from Havre, (Laboulbène '64), and Tréport, France, (Nicolet, '77) from St Andrews Scotland, and Kinsale Ireland, (Lubbock '73) and in this country from Nantucket, Mass. (Packard '73) and I have myself found it abundant at Annisquam, Mass. on the northern side of Cape Ann. It is found between high and low water marks, in crevices of the rocks, under small stones, or floating helplessly about in the tide pools where it frequently forms clusters of some little size. It is slow in movement and is easily captured, and according to Laboulbène feeds on small mollusks, it being only necessary to place one of these with its shell crushed near the crevices where the Anurida lives, to obtain large numbers of them. Collected from the pond

Preparation.—

The animals were placed either in an aqueous solution of Picro-sulphuric Acid to which a little Ether had been added or in Perenyi's Fluid similarly treated. In the former fluid the

specimens were left two hours and in the latter one hour after which they were slowly raised through different grades of alcohol to that of ninety per cent.

The Ether was added to dissolve the fatty matter with which these animals are covered that the killing agents might penetrate more rapidly.

After a few unsuccessful attempts to stain in toto I found that the best results were secured by placing the animals for about twelve hours in absolute alcohol, then in succession three hours in Chloroform, one hour in a solution paraffine in chloroform, three hours in melted soft paraffine, and finally, six hours in melted hard paraffine. These lengths of time were varied, but the ones here given proved about the best. The specimens were now imbedded and sections cut with a Schanze microtome at [illegible] of one of the sixty divisions of the screw-wheel, or about one four hundredth of a millimeter.

The sections were fixed to the slides with Meyers Albumen Fixative after coagulating which the slides were passed successively through turpentine, absolute alcohol, ninety, eighty, and seventy percent alcohol five minutes in each, then placed in Boehmers Haematoxylin for three minutes. They were then washed in one half percent alum solution to which an equal volume of ordinary alcohol had been added, and were then passed through the various grades of alcohol in the reverse order, placed in turpentine for

several minutes and then mounted in Canada Balsam.

External Anatomy.—

The adult insect is from two to three millimeters in length, rather linear in form, and of a shining blue-black color, lighter in young specimens. The body is distinctly divided into head, thorax and abdomen. The head is rather flattened and pointed in front, so that on side view it resembles a right triangle, the ventral surface representing the altitude, and its line of attachment to the thorax the base. On the dorsal surface of the head, in front, are the two antennae, simple and usually three jointed, though I have observed four joints in a few instances. (Fig. 46.) Lubbock '73 states that mutilation of the antennae is extremely common in this group, and that a reproduction of the lost part is frequent at the next moult. If so, this will explain the different number of joints in different individuals, but as the terminal joint in those having but three is in form and size like the terminal joint in those having four, besides bearing well developed sense organs, I am doubtful whether mutilation is the cause of this variation.

The terminal joint is usually somewhat larger than the others and bears on its tip a cluster of bristles, and on its dorsal inner surface

[illegible] At the [illegible] end of the [illegible] behind the base of the antenna, in a slight depression is a peculiar structure — the post-antennal organ — first described by [illegible] (4.) Just behind this is a cluster of five eyes, "ocelli" imbedded in a mass of pigment denser here than elsewhere.

The mouth (Fig. 3.) is nearly terminal only slightly ventral, and is a circular opening with a cleft extending back a short distance on the ventral median line.

The thorax consists of the Prothorax, Mesothorax and Metathorax, all distinct and each bearing a pair of five-jointed legs ending in a simple claw. There are no lobes or ridges on the dorsal surface of the thorax.

The abdomen consists of six segments. On the undersurface of the first segment is the Abdominal Vesicle or Ventral Tube which consists of a somewhat antero-posteriorly elongated protuberance with a median longitudinal cleft. Passing forward from the bottom of this cleft along the ventral mid line to the [illegible] end of the ventral side of the [illegible] — is a peculiar [illegible] structure. [illegible] opening on a small papilla of the fifth segment is the single genital opening. There is no external indication of any structure in the adult resembling the "spring" possessed by most of the Collembola but in the young,

[illegible] describes two processes on the ventral surface of the fourth segment which he considers a rudimentary [illegible].

Integument.

[illegible] integument consists of a hypodermis which secretes an external chitinous cuticula and rests upon a basement membrane (Fig. 2.). Its thickness varies, being less on the under surface of the animal and greatest on the head (Fig. 3.), but averaging from 0.03 m.m. to 0.04 m.m.

[illegible] filled by a dense black pigment, which in the specimens examined concealed all nuclei from sight, and which immersion of the sections in forty-five per cent of Nitric Acid for ten minutes failed to remove. In young specimens the pigment is less dense and does not fill the [illegible].

The cuticula also varies in thickness in different parts of the body, but is usually thinner than the underlying hypodermis. It is transparent [illegible] protuberances which show a tendency to an arrangement in rows [illegible]. When examined in section some specimens indicate a partial separation into two layers, one internal, the other external, the line of separation

passing just below the bases of the protuberances. Fig. 2.)

Scattered among the protuberances are long bristles, generally in small groups, many, probably all, sensory in function.

The basement membrane on which the hypodermis rests is apparently structureless, and marks the external limit of the body cavity. In many places this membrane is separated from the hypodermis by the fat body or as it is called by Sommer ('85), the "Exkretionsorgane" which attaches directly to the hypodermis, and over the surface of which the membrane is reflected.

In some places the integument undergoes special modification, especially in connection with the sense-organs. In each case, however, the superficial modifications are hypodermic and the cuticula is secreted as a [illegible] exception of the post-antennal organ, to this not being a real one.

Muscular System.—

[illegible] variation in different specimens. They attach themselves to the cuticula on its inner face at which points the hypodermis is somewhat modified, losing its pigment, and apparently becoming itself somewhat chitinous. Fig.

Where the attachments are internal they may be either to the tunica propria or to chitinous bodies, themselves held in place by other muscles passing in various directions to the outer surface.

[illegible] thin tie. They consist of from one fibre to several bundles, but each fibre [illegible] perimysium is also apparently present.

The muscles differ histologically, forming two classes. In one class the [illegible] seem very granular, have rather poorly defined outlines and only faint indications of the light and dim bands (Fig. 6). In the other class the outlines are very distinct, and the light and dim bands show plainly and [illegible]

[illegible]

The oral opening leads into a buccal cavity of considerable size which in longitudinal section (Fig. 3) is seen to divide posteriorly into a dorsal and a ventral chamber. The dorsal chamber is the beginning of the pharynx and is nearly circular in cross section. The ventral chamber is broad and bent dorsally at the sides.

A little behind the point of separation from the dorsal chamber it divides into two pouches, one on each side, which continue backward for some distance and also bend dorsally. Arising from the inner ends of these pouches and passing forward in the buccal cavity are two pairs of jaws, mounted on long hollow stalks. One pair arise dorsal and lateral to the other pair, the [illegible] in cross section [illegible] V with its lower angle unmarked.

The homologies of these jaws I have been unable to determine with certainty [illegible] the maxillae, and the others the mandibles, of the higher insects.

The maxillae [illegible] of these the middle one bears irregular blunt teeth, while that on one side has a large number which are long and fine, and that on the other [illegible] immovable, and are probably controlled by muscles which pass within the chitinous shell of the maxillary stalk from their tips to their bases.

The mandibles Fig. [illegible] end in a single blade like process bearing a few irregular teeth. A muscle [illegible] from the tip of the stalks to their bases but its function must differ from that [illegible]

mandibular muscle, as the mandibular process seems to be firmly fixed to the stalk and not attached to it by a joint.

The walls of the ventral chamber and of the two pouches are lined by granular cells with large deeply staining nuclei. They much resemble gland cells. They are covered externally by the chitinous cuticle lining the mouth cavity and fore gut, and which is here thin and delicate.

In the dorsal median line of the ventral chamber is a chitinous ridge extending forward to where this chamber joins the buccal cavity. The arrangement of the neighboring muscles seems to indicate that this ridge may serve as a sort of fulcrum for obtaining certain motions of the jaws, and as a firm attachment for other muscles running to different parts of the head.

The muscles for moving these jaws are quite numerous, and there are also sets of extensor and retractor muscles to move the chambers containing the jaws, themselves forward that the latter may protrude from the mouth, and to draw the chambers back into the cavity of the head. In this position the lateral pouches often extend nearly to the back of the head.

The pharynx bends upward and then backward extending to the anterior surface of the brain beneath which it passes through the [illegible] at the same time changing its structure and becoming the oesophagus. This extends to the posterior end of the mesothorax where it joins the mid gut. The pharynx and oesophagus together forming the fore gut.

The oesophagus is lined by a delicate chitinous cutical which is thrown into irregular folds (Figs. [illegible]). [illegible] it is a granular protoplasmic layer containing numerous round or oval nuclei. Cell walls are either indistinguishable or nearly so but longitudinal sections show [illegible] the cuticle alternating with the nuclei. The cells rest upon a very delicate tunica propria which separates them from the layer of circular muscles. Each muscle fibre completely encircles the oesophagus and the fibres are closely packed, side by side and are of the striped variety. In the median dorsal line is the nucleus of each fibre. External to this layer of muscle is a delicate [illegible] membrane [illegible] no longitudinal muscle [illegible]

The pharynx differs from the oesophagus only in having its circular muscle layer more developed, and in having dilator muscles — dilatores pharyngis — which attach themselves to the tunica propria pushing in between the circular fibres, and passing to their various points of origin. There are three groups of these muscles, two dorsal and one ventral. One dorsal group passes forward from its attachment, its fibres diverging to the right and left sides, and becoming joined to the body wall. The other dorsal group passes directly upward, in front of the brain, its fibres also diverging to the right and left. The ventral group runs directly back beneath the pharynx to a point between it and the suboesophageal ganglion. Here the fibres attach to a chitinous mass held in place by steadying muscles which pass in various directions to the body wall. The function of the dorsal group of muscles is to pull the pharynx forward and upward and of the ventral group to pull it back.

At the hinder end of the prothorax the oesophagus enters the anterior end of the mid-gut, into which it protrudes slightly, forming a papilla Fig. 2. As the mid-gut has about three times the diameter of the fore-gut and this papilla enters it close to its ventral wall a dorsal and lateral pocket is formed which has been homologised with the

proventriculus of the higher insects, but as it seems to me, on very slight grounds. The proventriculus in most insects is separated by a small tube from the stomach, which is the organ homologous with the mid gut, here, and can be easily understood as an enlargement of the oesophagus. If the tube posterior to it, and connecting it with the stomach, were pushed into the latter to form the papilla even then the proventriculus would not assume the position of this pocket, and I am more inclined to consider this structure as the incidental product of the union of the stomodaeum and mesenteron, and functioning as a sort of valve.

Just at the base of the papilla the circular muscles form a close ring and constitute what may together with the papilla be termed the Cardiac Valve.

The papilla consists of elongated, club-shaped cells, the larger ends protruding towards the mid gut. The cell boundaries are very indistinct. The papilla is evidently a part of the fore gut as it is covered by a chitinous cuticle, which ceases however at the bottom of the pocket described above (Fig. 2).

The mid gut extends to the end of the fourth abdominal segment, increasing slightly in its diameter towards its hinder end, but

contracting again before joining the hind gut. Its structure is quite uniform throughout. It consists of a layer of cubical almost columnar polygonal epithelial cells, each cell containing near its centre quite a large oval nucleus showing several chromatin [illegible] near their bases, and some have also a large spot of achromatin-like substance in some part of the cell. The free ~~edge~~ surface of the epithelium when examined with a Zeiss D. Oc. 4 shows a deep-stained narrow band, but under a one-twelfth inch immersion objective this becomes a narrow border outside the cell boundary, and apparently [illegible] fine hairs. I am inclined to believe that my [illegible] were not killed quickly enough to preserve these portions as well as could be desired, and that this border is the "Härchensaum" of Frenzel to which he finds in the mid gut of Crustacea and insects and which he apparently considers as a variety of ordinary cilia, for he says: "Die [illegible] -ärchen- Härchensaum) Zellen eintheilen."

The cell walls vary greatly in their distinctness, being quite marked in some, and hardly to be seen in others. I am inclined to attribute this latter condition also to poor preservation.

The epithelium is not thrown into folds but lies quite smoothly and rests on a very delicate tunica propria continuous with that of the fore gut.

The mid gut has both circular and longitudinal muscles. The former are much smaller than those of the oesophagus and are some distance apart (Fig. 11). Otherwise they are quite like those of the fore gut. The longitudinal muscles are also very small. They are scattered over the outer surface of the mid gut, external to the circular fibres, and are very unimportant in its anterior portion. In the posterior portion both layers become more extensively developed (Figs. 17, 15). External to all is an enveloping connective tissue membrane.

The appearance of the epithelium of the mid gut differs greatly at different times especially during ecdysis, and these changes will be described later.

The hind gut extends through the [illegible] and [illegible] abdominal segments and opens to the exterior [illegible] and two smaller ventral ones, placed almost at the extreme tip of the body. Where the mid gut and hind gut join the epithelium becomes columnar and forms a thickened band external to which is a bundle of circular muscle fibres forming a valve which

may be termed the digestive part.

The epithelium of the hind gut consists of low, granular cells, thrown into irregular folds and ridges projecting into the lumen. The cells rest upon a tunica propria which is very delicate. External to this are scattered circular muscles which do not follow the epithelium in its foldings and thus spaces are left between them and the tunica propria, Fig. 17. The epithelium contains large oval nuclei showing several chromatin granules. On the surface bordering the lumen is excreted a chitinous cuticle bearing neither hairs nor spines.

The circular muscle fibres which are attached to the tunica propria at intervals are of the striped variety and as in the mid gut each fibre completely surrounds the gut. External to these muscles is a connective tissue membrane which bends down on each side of the muscle fibres till it touches the tunica propria. In these hollows blood corpuscles may frequently be observed, and Sommer who observed a similar structure in [illegible] suggests that aeration of the blood takes place here. On the other hand the cavities appear to form a part of, and to be in free communication with the general body cavity, in which blood corpuscles are

abundant, and for this reason I see no indication that we have here to deal with any special mechanism more than anywhere in the gut. It seems to me that this relation of the muscles to the epithelium secures a more complete closure of the lumen, thus aiding in the expulsion of the faeces and accomplishing this more effectually than if the muscles were attached continuously.

No longitudinal muscles occur, but from various points on this portion of the gut, muscles — dilatores recti — pass dorsally, laterally and ventrally to the body wall, thus serving the same purpose as longitudinal muscles.

Certain features about the digestive tract as a whole, are worth noting. We have here evidently a very simple structure, [illegible] [illegible] from the stomodaeum, mesenteron and proctodaeum of the embryo, and but little modified therefrom. The three parts are separated by simple valves; there are no diverticula of either portion, and the histological structure corresponds, the epithelium, tunica propria, circular muscles and connective tissue membrane being present in all three portions. The chitinous cuticle of the fore and hind gut is replaced in the mid gut by the "Härchensaum," and the longitudinal muscles of the mid gut are, in the fore and hind guts replaced by dilator muscles passing outward to the body wall.

Fat Body.—

Occupying a large portion of the body cavity is a mass of tissue which constitutes the [illegible] [illegible] and which I regard as corresponding to the fat body of the [illegible].

In the first abdominal segment it consists of a large mass lying on each side of the gut and pressing against it, but having no prolongations to the outer surface of the body. In the metathorax occurs a prolongation to the hypodermis just ventral to the legs. Farther forward this attachment becomes lost, and anterior to the metathoracic nerve ganglion a lateral one appears. This also soon ends and in the region of the mesothoracic ganglion an attachment just external to the legs is formed. In front of this ganglion this [illegible] becomes lost and the [illegible] attachment [illegible]. At the prothoracic ganglion it again forms a prolongation to the body wall just external to the legs while the two portions which press against the sides of the gut, fuse and surround both it and the heart which [illegible] now bent ventrally into close proximity to the gut. [illegible] head this portion extends to the dorsal hypodermis to which it attaches [illegible] [illegible]

into two bands, one dorsal to the other. The dorsal portion passes forward becoming reduced in size, and [illegible] just behind the brain. The ventral band splits into a right and a left half, and these diverge passing around the sides of the brain just anterior to which they end.

In the abdomen the [illegible] of the fat body are more voluminous and it seems to occupy the greater part of the body cavity, attaching itself at many points to the hypodermis.

Similar masses of tissue occur in various portions of the body. Two particularly noticeable masses lie one on each side of the ventral nerve cord in the thorax. In many places the hypodermis is [illegible] by a narrow strip of this tissue.

When examined with the microscope the fat body is seen to consist of a reticular network of fibres enclosing many irregular portions and containing many large deeply staining nuclei. These at times are clearly defined by an external membrane which is continuous with the basement membrane of the hypodermis where the fat body is attached to the body wall.

Sommer ([illegible]) describing a similar structure in Tomocerus states that it contains large numbers of concretions of a [illegible] in direct light and pale green in reflected light and which appear to

consist of calcic carbonate ($CaCO_3$). In my specimens, with two exceptions I have failed to find any trace of these concretions. These two exceptions however show imbedded in the reticular tissue what appear to be large granular irregular shaped masses of a dark [illegible] color. More than this I have been unable to ascertain. From their entire absence in most examples I conclude that they are transient formations, or else that they were entirely dissolved by the action of the acids used in the processes of preparation except in the two cases mentioned. In those cases the granular masses seemed unaffected by the stains, as one specimen was stained with [illegible] Haematoxylin and the other with Grenachers Borax-carmine, yet the color of the concretions was the same in both.

Circulatory System.

The circulatory system consists of a dorsally placed heart anteriorly continued as an aorta, and of the body cavity. These contain the plasma and corpuscles constituting the blood.

The heart lies on the median dorsal line just beneath the hypodermis, and ends posteriorly just above the junction of the mid gut and hind gut at the pyloric valve (Fig. 15). From its [illegible] end

[illegible] rounded, a thread of connective tissue runs back a short distance and attaches to the dorsal epidermis on the [illegible]

From its hinder end the heart passes forward along the dorsal wall (Fig. 20) to the region of the fore gut, then it bends down towards the gut, to which it becomes attached by connective-tissue fibres (Fig. 21). At the cardiac valve its structure is unchanged but it becomes slightly smaller, and there being no ostia anterior to this place, it is now termed the aorta. It rests directly upon the dorsal wall of the fore gut. Passing forward we find the relations of the two changing: at the front portion of the mesothorax (Fig. 23) it becomes flattened and at the back of the head (Fig. 25) more than half encircles the oesophagus. A little farther forward it entirely surrounds the gut, the walls of which are bathed on all sides with blood, that portion of the aortal wall which was reflected around the gut apparently disappearing, or else forming a part of the external limiting membrane (Fig. 26). Just behind the brain (Fig. 27) the aorta while still encircling the oesophagus stretches downwards till its ventral wall comes in contact with the sub-oesophageal ganglion. Beyond this point I have been unable to follow the vessel definitely, but from a study of a number of specimens I am inclined to think that it breaks up into a large number of small

vessels so short as hardly to deserve the name, which open directly into the body cavity.

The heart is held in place by five pairs of alary muscles placed between the second and third thoracic, third thoracic and first abdominal, first and second, second and third, and third and fourth abdominal segments. These muscles pass laterally to the dorsal wall on each side where they attach themselves to the hypodermis between the dorsal and dorso-lateral bands of longitudinal muscles of the body wall. They are triangular in outline, broadening as they approach the heart, near which they form two layers, one passing to the dorsal surface, and the other to the ventral surface and there ramifying (Fig. 9). In the space thus left between these two layers, the heart wall is bent inward and in the hollow thus formed is a small ostium opening into the cavity of the heart. The ostia appear to be in direct communication with the body cavity, as is the anterior end of the aorta, and the greatest portion of the circulation seems to be accomplished in the spaces between the fat body and the body wall. Valves were not observed in the ostia of the heart but are probably present. The walls of the heart have an outer muscular coating and in some cases indications of a [illegible] [illegible] [illegible] [illegible] [illegible]

Blood corpuscles occur in all parts of the circulatory vessels and in the body cavity. They are circular in outline and have a prominent nucleus. Their number appears to be very great.

Where the blood is aerated is uncertain as there is no tracheal system present, but this question will be recurred to later.

Nervous System.--

The nervous system consists of a superoesophageal ganglion or brain, joined by a double commissure enclosing the oesophagus to a suboesophageal ganglion and following which, and joined to it and to each other by double commissures are three ganglia situated in the prothorax, mesothorax and metathorax respectively.

Nicolet (47) states that in the Collembola there are three ventral ganglia, two thoracic, and one abdominal one related to the reproductive functions; but he is clearly in error. Sommer (55) speaking of Tomocerus, says that it has a brain, a sub-oesophageal ganglion, and four ventral nerve knots three thoracic and one abdominal. Lubbock [illegible] says "the nervous system [illegible] consists of five ganglia two of which the supra- and infra-oesophageal [illegible] * * * The linear species have generally two

ganglia in the thorax and one in the abdomen." If these observations can be given any value it indicates that the number of ganglia varies in different species and that no general statement for the group can be made.

The brain of Limulus is rather oval in outline when viewed from above; its long axis transverse to that of the body of the animal.

It rests closely upon the fore gut, over the sides of which it is continued down and which it more than half surrounds, Figs. 35, 36. A stout process leads forward on each side from the lower part of the anterior face, which becomes prolonged as the antennal nerve (Fig. 37). Farther back the dorso-lateral portion of each side becomes partially constricted off forming the optic lobe continued out as a stout optic nerve which almost immediately divides into five branches passing to the five ocelli of that side. These branches are termed the ocellar nerves (Fig. 35). In this same vertical plane also, the ventral prolongations of the brain around the oesophagus form a trunk on each side, which passes downward and joins the suboesophageal ganglion, thus forming the circum-oesophageal commissure (Fig. 3). Posterior to this plane the brain abruptly terminates.

The circum-oesophageal commissure [illegible]

and is roughly cylindrical in form. From its anterior end a pair of stout nerves pass forward to the buccal pouch Fig. 8 bn. A little behind this on each side it gives off from its dorsal [illegible] a large nerve which passes back branching as it goes to the posterior extremity of the buccal pouch of that side. This nerve contains a large number of nuclei in a row along its axis. Just below this a smaller nerve is also given off from the ganglion. At its posterior end the ganglion is continued into two large lateral commissures and a small median one all three leading directly backward to the prothoracic ganglion, the two lateral commissures [illegible] between [illegible] the ganglia.

The prothoracic ganglion is shorter than the last. From near its middle it gives off a large trunk to the outside of the prothoracic leg on each side and just posterior and ventral to this another branch to the inside of the leg.

Between this and the mesothoracic ganglion there is only the lateral pair of commissures each commissure giving off in its course a [illegible].

The mesothoracic ganglion is like the prothoracic ganglion

in form. It gives off from near its middle a single nerve trunk on each side and it is joined to the metathoracic ganglion by a [illegible] [illegible].

The metathoracic ganglion (Figs. 39, 40) appears to result from the fusion of two. About one third of its length from its anterior end it gives off a pair of large nerves which almost immediately branch. Near its posterior end it gives off a pair of small nerves, and at its posterior end two large nerve trunks which pass backward along the ventral side of the abdomen (Figs. 34, 45, v.n.), to the fifth segment. Here they break up, the largest branches passing to the genital glands close to where these enter the genital ducts. Between the metathoracic ganglion and the fifth segment they give off a number of branches to the different segments of the abdomen.

In the feet, especially in the two most distal joints the nerve fibres enter small ganglia each consisting of two or three cells (Fig. 35). In these cells are very large, deeply staining nuclei.

The histology of the nervous system offers little of [illegible]. The brain and other ganglia have an external layer of [illegible] ganglion cells the walls of which are sustained in [illegible]

while the nuclei stain deeply Figs. 33–36. These cells seem to be aggregated into lobes in a slight degree. Besides the ganglion cells there is a central portion which does not stain and shows [illegible] of nerve fibrils passing in various directions. Over the surface of the brain and ventral ganglia is a tough, dense layer [illegible] tissue.

In the ventral ganglia the unstained fibrillar mass is in two bundles, surrounded by ganglion cells Fig. 39 and these [illegible] between the ganglia.

Near where each nerve trunk leaves the central nervous system [illegible]

These may lie just where the nerve enters the ganglion Fig. 37 or in the nerve itself Fig. 39 and in the latter case they may be near the ganglion or at some little distance from it.

That these large ganglion cells — for such they must be [illegible] evident, but their size as compared with that of the ganglion cells of the ganglia is so great that I am at a loss for a definite explanation and I can find no description of any such nerve cells

having been observed in any situation.

The two abdominal trunks appear to contain no ganglion cells anywhere in their course.

Sense Organs.—

These organs are quite well developed and are of great interest as they have been but little studied and the functions of some are wholly unknown.

Tactile Organs.— Long bristles plentifully distributed at intervals over the entire surface of the body have every indication of being tactile organs. They are especially abundant around the mouth and on the antennae where they form a dense clump at the tip, Fig. 40. A fortunate longitudinal section of an antenna (Fig. 47) shows at the base of a bristle a small bit of nervous tissue from which one nerve fibre passes up into the bristle while another passes out to join the antennal nerve.

Some of these bristles may perhaps have other than [illegible] functions.

A problematical organ, first discovered by Kingsley '84 in Campodea is present here, but in a more complicated form. As described for Campodea it is a small bilobed organ near the [illegible]

antenna. No description of its histology was given and its function is unknown.

In Anurida it occurs on the upper inner side of the antenna near the tip of the terminal joint (Figs. 46, 48). It is trilobed and its base rests in a slight depression of the cuticula. In section, Fig. 47, we see that the lobes are only separate in their outer halves, uniting in the half [illegible] the point of attachment. The [illegible] are [illegible] smooth and follow the surface of the hypodermis which lies [illegible] smooth. A good sized nerve [illegible] the organ, [illegible]

Its function can at present be only surmised, but the three lobes are so placed relative to each other that they might easily give the insect some idea of the form of [illegible] as they do to the three dimensions of space. Some species of Collembola are wholly blind, while others have only such simple eyes that their vision must be at best extremely poor and from these considerations and from the location of the organs in question I am inclined to regard them as organs of form supplementing the [illegible]

Eyes. — Compound eyes do not occur in any of the Collembola and the number and arrangement of the ocelli appear good specific and

generic characters."

Templetonia has one, Orchesella six, Tomocerus seven and Smynthurus eight ocelli on each side. They are usually placed in a mass of pigment [illegible]

[illegible] cuticula of which is smooth. Vertical sections (Fig. 42) show that each [illegible]

[illegible] the hypodermic cells.

[illegible]

[illegible] of four cells of the hypodermis their [illegible] walls becoming lost, and the [illegible]

Post Antennal Organ.— This curious structure (Fig. 71, p.a.o.) was discovered by Laboulbène who proposed to call it the organ postantennal [illegible]

a corresponding structure is present in some species which have no ocelli, and he therefore suggested the term "post-antennal" which has been generally adopted.

Laboulbène [illegible] est formé par des espaces colorés tels que les représente la figure 7; leur couleur est très-noire. Le nombre des cercles rapprochés varie de 7 à 8, le plus ordinairement il y en a 7 mais je dois noter que j'en ai trouvé parfois 8 d'un côté et 7 de l'autre. Sur les jeunes individus la disposition est très curieuse, la figure 9 en donne une idée; il existe alors 22 à 24 espaces comprimés et serrés les uns contre les autres avec un espace central libre: le tout rappelle la forme du fruit chez les plantes ombellifères [illegible] entre les *[illegible]* et les *[illegible]*. Quelque soin que j'aie mis à chercher si du point central il naissait un poil allongé ou toute autre production dermique, je dois dire que je n'en ai point trouvé."

In the examples I have examined, the organ consists of an irregular circle of oval bodies with an external cuticular covering and an internal portion filled with black pigment and connected with the hypodermis beneath. The number of oval bodies varies from seven to nine, and like Laboulbène I have observed a few

specimens with seven on one side and eight on the other. The usual number however is seven.

These organs occupy a slight depression on each side of the head between the antennæ and ocelli. Near the organ the elevations of the cuticula cease, and over the surface of the organ itself it lies smoothly (Fig. 43).

Focusing more [illegible] than is represented in Figs. 41 and 44, a faint circle appears at the inner end of each oval body. Vertical sections (Fig. 43) show this circle to be the outline of a pedicle or stalk on which each organ is mounted and through the centre of which connection between the pigmented protoplasm occupying the centre of these bodies (seen in Fig. 43) and the protoplasm of the hypodermis is maintained.

The function of this organ is unknown. I have endeavored to find some nerve connection with the brain but on account of the amount of pigment surrounding it I have been unsuccessful. In one instance I thought I discovered a nerve leading from the brain just anterior to the optic lobe, to it, but while such a nerve from the brain certainly passes in that direction it enters the pigment mass a little to one side, and beyond that point I have

failed to follow it.

The function of this organ is unknown. One is naturally inclined to consider it as in some way possessing a visual power, but there is no evidence supporting this view and the structure does not materially aid in a decision.

[illegible].—

The abdominal vesicle or ventral tube of the Collembola is an organ of great interest. Its form and relations differ greatly in different species but a description of its comparative structure in different forms, and a discussion as to its functions is reserved for later consideration.

In Anurida maritima it is a large protuberance on the ventral side of the first abdominal segment. It is divided into halves by a median longitudinal cleft, so that it may be either considered a bilobed structure, or as formed by a pair of separate protuberances pressing together. Cross sections of the animal in this segment show that the cuticula follows all the folds of the surface, Fig. 37. The [illegible]

Beneath the cuticula on each side of the vesicle the hypodermis

shows its normal structure and this is unchanged on the lateral sides of the vesicle itself. At the tip of each lobe however its [illegible] [illegible] the cuticula of the longitudinal cleft in which the usual small protuberances of the cuticula are absent. Several muscles pass from the body wall into these lobes which may thus be retracted in some measure.

Leading forward from the abdominal vesicle on the median line [illegible] in Fig. 33, in the mesothorax, and in Fig. 32 under the head. This tube originates at the base of the median cleft at the anterior end of the vesicle [illegible] with a groove separating them. In both figures the cuticula and hypodermis have been torn apart, and the former has preserved most [illegible]

Farther forward the two outgrowths instead of remaining [illegible] fuse together and in this [illegible] a single tube Fig. 32.

In the postero-lateral and dorsal regions of the head is a mass of

side which I at first supposed to be the salivary glands, Fig. 29. Their histological appearance is that of salivary glands and on each side of the head a convoluted duct (Fig. 30) leads downward, then forward to the buccal cavity. Here it is joined by the duct from the other side of the head and the median duct thus formed [illegible] to the posterior end of the median cleft of the mouth, gaining a [illegible]. Here I was surprised to find that instead of leading upward to enter the buccal cavity it went downward passing through the ventral cleft of the mouth (Fig. 31) and communicated directly with the tube leading forward from the [illegible] vesicle.

[illegible] a careful study with high powers, of about twenty-five specimens only confirmed my previous work and I am therefore compelled to think that though occupying the position of salivary glands, and with ducts having the usual course of salivary ducts these glands must have some other function. It is possible that they may have a connection with the buccal cavity also, by some branch from the main duct, but I have failed to prove any such arrangement.

The histology of the gland and of the ducts is similar to that

of the salivary glands and ducts of the higher insects. The cells of the gland (Fig. 29) are granular, with prominent nuclei; those of the ducts are cubical with indistinct boundaries (Fig. 30) and smaller nuclei.

Ventral Spring.—

In young examples of this species, Ryder ('86) describes a rudimentary pair of processes on the ventral surface, pointing forward from the anterior edge of the fourth abdominal segment.

[illegible] in a rudimentary [illegible] no trace of it [illegible] in the adult. [illegible] in the same place [illegible] in sections two nearly spherical masses of cells slightly resembling [illegible] separated from the hypodermis by the fat body which here lines the body wall (Fig. 45).

What these masses represent I do not know unless they are the [illegible] of the structure [illegible] in a stage of degeneration, remaining after all external trace of the structure [illegible] spring it is of much interest, as indicating that the differences between the spring-less Collembola and those which possess a developed spring are due to a degeneration of the former group.

Genital Organs.—

The genital organs lie ventro-lateral to the abdominal portion of the digestive tract but may extend forward into the mesothorax. Both the male and female organs consist of a pair of simple tubes of varying diameter containing the reproductive elements. At their anterior ends these tubes are attached by a cord of connective tissue which passes forward and joins the ventral body wall. Posteriorly each tube opens into a duct which soon unites with that of the [illegible] median duct [illegible]. In the female a ventral diverticulum from this portion of the duct is also present. The genital opening is situated at the tip of a small papilla on the hinder edge of the fifth abdominal segment on the middle line of the ventral surface of the body.

Female Genital Organs.—

[illegible] when distended with eggs may be pressed dorsally till portions may become dorsal to it. Externally the tubes are covered by a sheet of dense connective tissue, within which lie cells of various sizes containing very large nuclei, and a large number of

yolk spheres.

The anterior end of the ovary (Fig. 56) is drawn out into a narrow tube which is filled with granular protoplasm and small oval [illegible] distinct nucleoli. [illegible] the tube the nuclei become more spherical and pass to one side, along the wall of which they form a sort of germinal ridge. The nuclei increase rapidly in size and gather the protoplasm about them forming cells (Fig. 57). These cells are pushed out from the germinal ridge by cells forming in [illegible] and these are in turn pushed [illegible] [illegible] across it (Fig. 55).

Soon a sort of degradation occurs, many of the cells of each row becoming completely destroyed. In this change the nuclear chromatin leads the way, forming irregular scattered granules, and this change continues [illegible] [illegible] more than one, I cannot say.

[illegible] sizes at first small, but rapidly enlarging, and gradually become

the yolk which is very abundant in each ovum.

As the ova pass backward along the ovarian tube, they in some way acquire an enclosing membrane, but how and just where, I cannot say. Even near the opening of the oviduct each ovum has several cells of the row from which it was formed still intact and the final breaking down of these cells must occur very late in the maturation of the ovum.

Passing from the ovary is a narrow oviduct (Fig. 53) consisting of granular cuboidal epithelial cells, resting on a delicate tunica propria, and containing small spherical nuclei. The oviducts of the two sides soon unite, and the two together form the vagina, which has a wall of large columnar cells, broader on their attached edges than at the lumen. The nuclei of these cells are large, [illegible] and contain prominent nucleoli. The cells rest upon a tunica propria, continuous with that of the oviducts, and bear on their faces which form the lumen, a chitinous cuticle (Fig. 54).

From the ventral side of the vagina a small diverticulum passes forward (Figs. 53, 54) which may possibly be a receptaculum seminis, and which is slightly bilobed at its anterior end. The cells of this diverticulum are quite granular and the cell walls

are less distinct than those of the vagina, and fewer nuclei are present. Externally the cells rest upon the tunica propria, and internally they are lined by a continuation of the cuticle of the [illegible] the lumen of the diverticulum.

No circular muscles are present around these ducts, but dilator muscles — dilatores vaginae — are present, leading to the body wall (Fig. 53).

At the genital opening the cuticle of the ducts becomes continuous with the cuticula of the external surface of the body.

Male Genital Organs.—

The testes, like the ovaries, are a pair of long tubes extending backward from the mesothorax. They differ greatly in their histological structure at different stages of maturity.

The immature testis is shown in cross section in Fig. 49. It is surrounded by a dense layer of connective tissue, and consists of a mass of protoplasm [illegible] more than [illegible]. At this age the whole testis has the same

structure. Farther development begins at the posterior end, and passing forward from that point successively earlier stages of the development are met with.

If we examine a mature testis we find at the anterior end the [illegible] shown in Fig. [illegible] Farther back the structure changes to that shown in Fig. 59, the granules becoming more concentrated and septa appearing. A little behind this point the granules elongate and from them pass fine fibres or threads which form bundles lying in various directions (Fig. 50). The nuclei are still present, scattered through the substance of the testis, and at one point a structure slightly resembling a germinal ridge occurs (Fig. 50, g.r.). The appearance of this part of the testis is also shown in longitudinal section in that portion of Fig. 58 near the line AB.

Behind this the structure soon changes. The entire substance begins to undergo degeneration; the threads become lost, the septa disappear, and we get a condition shown in Fig. 60, and along the line CD. of Fig. 58. Soon the nuclei [illegible] small numbers, Fig. 61, and along the line EF of Fig. 58), and soon a [illegible]

[illegible]

and indistinct cell boundaries. A somewhat similar appearance of that portion of the granular mass nearer the centre of the tube may also be observed (Fig. 58) forming a zone separating the unchanged granular mass along the line [illegible] Fig. 58 [illegible] the mass of fat globules and [illegible] follows. The line GH. of Fig. 58 crosses the mass of fat globules, and also a portion of the separating zone. Passing back the fat globules increase in number and nearly fill the posterior part of the testis, while among them are multitudes of spermatozoa with elongated rod-like heads.

This process of spermatogenesis may be summarized as follows. The granular groups (Fig. 49) become greatly developed and form distinct groups containing elongated granules (Fig. 50). This structure is soon broken down and a quite homogeneous mass results, containing many deeply staining bodies like the granules of the earlier stages (Fig. 60). These granules soon become more prominent, while the remainder of the substance present, collects around the scattered nuclei present, forming epithelial cells. In these cells or by modifications of them, the fat globules and spermatozoa are formed and make their way into the lumen of the testis.

I have met with no description of spermatogenesis in [illegible]

which seems to agree with this process, and I have therefore endeavored to represent only such conditions of structure as were plainly to be seen, without an attempt to explain the various changes undergone.

The testis opens into a short vas deferens consisting of low cuboidal epithelial cells resting on a tunica propria. The vasa deferentia soon unite and form an ejaculatory duct (Figs. 51, 52, 63) lined by a chitinous cuticle continuous with the cuticula of the outer surface of the body. In some specimens (Fig. 63) this is thrown into ridges on the ventral wall of the duct, but in other cases (Fig. 51) these appeared to be entirely absent.

Beneath the cuticle are large granular columnar epithelial cells, with distinctly staining nuclei. At the external opening of the ejaculatory duct these cells bend each way and are continued along the surface, retaining their columnar character to some distance (Fig. [illegible]) [illegible] the normal structure [illegible] hypodermic cells (Figs. 51, 63). These cells rest upon a tunica propria continuous with that of the vasa deferentia. No circular muscles occur, but dilator muscles (Fig. 63) running to various parts of the body wall, and serving by their contraction to enlarge the ducts, are met with.

Molting.—

The process of molting is much the same as in other Arthropods. The external cuticula, the cuticle of the fore gut, hind gut and of the genital ducts is shed with each molt.

In the mid gut, just before ecdysis a peculiar change occurs. The nuclei of the epithelium divide, and one of the two which are thus formed in each cell passes towards the free face of the cell while the other passes towards its base. The cell walls now become indistinct and degeneration occurs, the outer half of each cell being thrown off. These molted cells collect in the lumen of the mid gut and remain there (Figs. 14, 15.) till the chitin of the remainder of the body is thrown off, when this is also removed [illegible] the inner edges of the cells remaining form a new "Stäbchensaum" and resume their normal condition.

General Considerations —

Two problems in connection with the anatomy of the Collembola require further consideration. These are: 1. the relations of the fat body to the hypodermis, and an examination of the [illegible]

abdominal vesicle and of the glands in the head to which it is joined by the small ventral tube and the homologies of these parts.

The fat body of the higher insects is regarded as of mesoblastic origin and any protoplasmic relations it may acquire with the hypodermis must be regarded as of a secondary nature.

[illegible] seems that the structure is epiblastic and not homologous with the fat body of other insects.

If we consider the method of formation of the body cavity in Arthropods as described by Sedgwick ('87) for Peripatus we find that in the solid mesoblast a series of splits appear, enlarge, fuse and form cavities of varying form and size, constituting a body cavity of the type termed by Lankester a haemocoel.

As the mesoblast on the one side lies closely against the hypoblastic mesenteron and on the other against the epiblast which is to form the hypodermis, the relations of the fat body to these may be explained as follows.

The layer of mesoblast cells next to the split becomes flattened and forms a [illegible]

Where the mesoblast is several layers of cells in thickness the

middle layers do not become flattened but form the mass of the fat body of the adult. Where the body cavity is so large that but a single layer of mesoblast cells remains between it and the hypodermis this layer, as elsewhere becomes endothelial and [illegible] [illegible] the hypodermic cells and. In connection with the gut it forms the external [illegible] membrane which is lacking where the unmodified cells of the fat body and of the gut meet. At these places however there seems to be a sort of membrane between the muscles of the gut (which are [illegible] in origin) and the fat body. This membrane may perhaps be derived from a flattening of the layer of cells of the fat body which is nearest to the muscle layer and would correspond to the limiting membrane of the haemocoel, and it is possible that a membrane similarly formed between the hypodermis and the fat body marks the distinction between the two, seen in the higher insects. Strings of mesoblast cells passing through the body cavity or along its walls [illegible]

The fat body is so universally present in insects, Myriapods and in Peripatus that it must be looked upon as a very primitive structure and as already stated appears to be mesoblastic

in origin. I have failed to observe any protoplasmic connection between the fat body and the hypodermic cells in Anurida but if Sommers observations on Tomocerus are correct, then notwithstanding the [illegible] in position to the fat body; and which except in its relations to the hypodermis might be regarded without difficulty as mesoplastic, we [illegible] cells have secondarily acquired a connection with the hypodermis.

Sommer declares in favor of the first of these views and decides that this structure is not homologous with the fat body. My own inclination is to accept the other view, and question the actual existance of protoplasmic connection between the cells of the fat body and of the hypodermis.

The abdominal vesicle has been differently interpreted by different writers. By Latreille and Kolenati it was regarded as a genital organ: Bourlet considered it as adhesive, an aid in easing the shock of alighting after a jump, and as serving to hold and moisten the spring. [illegible] Lubbock and Tullberg consider it an adhesive organ. Reuter says that water is gathered to the mouth from the surface of the body by the tarsal claws, from which it is placed by the "Kopflappen" in the

[illegible]

that it may possibly have a function similar to that of the oil glands [illegible]

It differs in structure in different genera. In Podura, Lipura and Anurida it is a simple soft tubercle. In Tomocerus it is enlarged, forming a tube bilobed at the tip. In Smynthurus it has a similar structure, but "from the end of the tube the animal can project [illegible] long delicate tubes provided at their extremity with numerous glands." No one seems to have observed the connection of the little tube leading forward with the vesicle and with the glands in the head.

[illegible] spiracles have been observed in Podurae; but according to my [illegible] their organs of respiration consist merely of an open canal along the underside of the head and the thorax, and it is in the [illegible] end of this canal under the head, that the tracheal system [illegible] whenever it exists, as in some of the larger Smynthuri.

This view seems to be unsatisfactory as opportunities for the purification of the blood are in no way afforded by the [illegible] position of the tube, while its connection with the glands of the head seems to indicate that its functions must be other than [illegible]

[illegible]

[illegible]

held on its back — a position from which it has some difficulty in recovering its feet — and if while in this attitude a piece of paper is brought within its reach the animal will endeavor to seize it with the feet, but at the same time it will project one or both of the ventral tentacles and apply it to them, similar to the sacs [illegible]

[illegible]

The comparative studies of Haase, 89, on the ventral sacs of Scolopendrella, Diplopoda, Thysanura and the abdominal vesicle of Collembola [illegible] structure and functions of the abdominal vesicle I give in his own words taken [illegible]

1. [illegible]

[illegible]

2. [illegible]

[illegible] Seiten die Abdominalsäcke nur bei vollkommener Ruhe des Thieres und in feuchtwarmer Luft hervor; bei Poduren liess sich unter dem Mikroskop ein bedeutende und schnelle Durchströmung des ausgestülpten Ventralschlauches durch Blutflüssigkeit in der Richtung nach dem Vorderende des Körpers zu, verfolgen.

9) Beobachtungen über das Kriechen der Poduren an Glaswänden zeigen, dass der Ventralschlauch dabei oft unthätig ist wie die Abdominalsäckchen in gleichem Falle stets bei Machilis.

[illegible]

Ventralsäckchen ergeben ebenfalls, dass letztere eine respiratorische Function [illegible] Stigmenpaar bei Smynthurus und Scolopendrella durch drei bei Campodea: das Tracheensystem ist in Rückbildung begriffen bei Lysiopetalum Polyzonium und ausserdem erst wenig entwickelt bei Machilis mit der Ausbildung der gemeinsamen Längsstämme erfolgt die Rückbildung der Ventralsäckchen." [illegible] the [illegible] a slight [illegible] function for the purpose of adhesion as described by Lubbock in [illegible] been recently required.

[illegible]

[illegible]

[illegible] It may be that the relations of these [illegible] in America [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Notes on Lepisma saccharina Linn.

This little animal is a pest to housekeepers, eating cloths, tapestry [illegible] [illegible] the paste and eating holes in the leaves and covers of books. It is from six to nine millimeters long, of a silvery white color, and with the division into head, thorax and abdomen distinctly marked.

[illegible] antennae rather more than half as long as the body. Posterior to the [illegible] the head. [illegible]

[illegible] reduced [illegible]. It has three pairs of well developed [illegible] [illegible]

[illegible] ten segments, the second and ninth being [illegible] short. From the terminal segment three long [illegible] [illegible] are given off.

In the female an ovipositor is present, which the drawings given by Grassi, (Pl. I, Fig. 27) indicate as being composed of a pair of processes from the seventh sternite and a pair from the eighth. The figure also shows on each of these segments and upon that which follows a pair of lateral processes — "pseudozampe." Grassi [illegible] differs [illegible] which he terms the "Abdominalgriffel" he says: "Bei Lep. saccharinum kommen nur an den zwei vorletzten Hinterleibsringen Abdominalgriffel vor, und zwar sind dieselben am achten Segment 0.6, am neunten aber 1.5 mm. lang." Thus he finds but two pairs instead of three. He states that in a Trieste species the ovipositor arises as in Machilis which he describes thus: "Sie [illegible] Zwischen [illegible] beiden inneren Ventralanhängen des achten und neunten Abdominalringes [illegible] und umgeben die am Ende des achten oder eher, wie es die Regel scheint, [illegible]."

The surface of the body is covered by scales resembling those of the wings of butterflies, and in many places occur groups of bristle-like hairs which probably have a sensory function.

I am not quite certain as to the species which I have studied, as while it agrees fairly well with the descriptions of L. saccharina in

the insects instead of its scales having from twenty to twenty-one rows (Beck: Lubbock, '73), they have nearly twice that number.

[illegible]

no Ether was added to the killing fluids.

Integument.—

[illegible]

[illegible]

The hypodermis contains no pigment and consists of a single layer of cells with large closely packed nuclei (Fig. 80) and with the cell boundaries not brought out by the stains used. The cuticula is not covered with protuberances as in Thysanura but is smooth and perforated by the pedicels of the scales. These (Fig. 85) vary somewhat in form and size, they have parallel longitudinal ribs between [illegible] and a short pedicel which penetrates the cuticula nearly to the hypodermis. The scales are attached at their anterior ends and their free edges overlap the scales next posterior to them. It is these scales which give the silvery gloss to the living animal.

The hairs which are present on some portions, appear to have some connection with the hypodermis (Fig. 78) as the entire thickness of

the chitin at their places of attachment appears somewhat modified.

On the dorsal surface of the thorax the cuticle is much modified at [illegible] [illegible] attached. At various places on the body the integument seems to have been folded in on itself to form processes for the attachment of muscles. One such is very noticeable in longitudinal sections of the animal located on the anterior face of the head, which [illegible] process in a horizontal direction.

Muscular System. —

[illegible] are more developed in Lepisma than in Anurida. Other differences in [illegible]

Histologically there is little worthy of note except that in some [illegible] which lie at or near the centre of the fibrils (Fig. 55) are present in [illegible] into bundles, than in Anurida.

[illegible]

Digestive System.—

The mouth is situated on the ventral side of the head and is bounded anteriorly by the labrum which is a broad flattened portion of the ventral integument at that place. Close behind this at the sides of the mouth opening are the mandibles (Fig. 69). These are stout chitinous [illegible] surface at the base of which is a cluster of short bristles. Muscles [illegible]

The maxillae which next follow, are smaller and consist (Fig. 70) of a lacinia bearing two pointed teeth and a few scattered bristles, a rounded galea, and a palpus which projects at right angles to the maxilla and which is composed of five quite long cylindrical segments, covered with hairs. The labium [illegible] which forms the posterior border of the mouth, consists of a double bifid lip and a pair of three jointed palpi, with a small plate overlying the basal joint and which is usually regarded as a fourth segment, but which is considered by Grassi whose figure I reproduce here as not constituting any part of the palpus proper. The terminal segment of the palpus is the largest, is flattened, and bears at the end three Grassi (Fig.) or more sixteen (Fig.) sense organs.

Surrounded by these mouthparts is the oral opening which leads into the [illegible]. This passes dorsad and somewhat forward for a short distance, then turning posteriorly passes beneath the brain through the circumoesophageal commissure, and enters the thorax, gradually increasing in diameter and changing in its histological features. This portion, which extends to about the end of the fourth abdominal segment, may for convenience be termed the oesophagus, though it passes insensibly into the pharynx at its anterior end.

The pharynx (Fig. 72) is composed of four layers. Resting on a basement membrane (tunica propria) is an epithelial layer which is thrown into very irregular and strongly marked folds. In this layer nuclei occur, but no cell walls are apparent. Separating the epithelium from the lumen of the pharynx is a layer of chitin which follows every epithelial fold. External (towards the body cavity) to the basement membrane is a layer of circular striated muscles. These are closely packed side by side at the beginning of the pharynx and show frequent nuclei which unlike those in Anurida have no [illegible]

[illegible]

separate leaving a little space between each two. No longitudinal muscles are present. External to all is a connective tissue

sheath — the lining membrane of the body cavity. In the [illegible] the epithelial folds become smaller, and finally disappear Fig. 73

Near the end of the fourth abdominal segment the oesophagus [illegible] forming a tube less than half the size of the oesophagus.

This tube which is called by Korelli the crop, has a slight ventral curvature. Near the end of the fifth segment six longitudinal chitinous bands appear in its walls, their bases, and dividing into six parts the layer of circular muscles which is here greatly developed. These bands project into the lumen of the [illegible] [illegible] [illegible] arises on the oesophagus near the end of the third abdominal segment and passes back to this region, but its exact distribution I have failed to ascertain. Beyond the chitinous bands of teeth the lumen of the digestive tract becomes smaller, turns dorsally [illegible] the mesenteric portion of the tract — the stomach.

The stomach at its anterior end consists of six blind pouches, [illegible] near to the end of the oesophagus. The ventral pouch on each side fuses with its fellow as it passes backward and into this then the two more lateral ones on each side, and the crop on the [illegible] line. [illegible] segment, where it abruptly turns to the left and then towards the head, forming a half circle, where it ends. The ileum which now [illegible] gives off the Malpighian tubes, and turns posteriorly, completing the circle and passing dorsal to the stomach. About one segment posterior to this point it enters the rectum, which is a large irregularly shaped chamber with a number of diverticula. This finally narrows into a [illegible] short straight [illegible] of which dilator muscles pass in different directions to the body wall.

[illegible] be described. The stomach (Fig. 77) has a well developed [illegible] [illegible] oval nuclei, and indistinct cell walls. There are a large number of small crypts in the epithelium, which have a glandular appearance. [illegible] (87) however mention

a similar condition in Orchestia maritima says that the [illegible] [illegible]

secretion, lie in crypts which are not considered as having a glandular nature. [illegible] The ends of the villi [illegible] [illegible] bear what seems to be a "Härchensaum" which has already [illegible] [illegible] [illegible] [illegible] [illegible]

propria external to which is a layer of circular, striped muscle, and a few [illegible] [illegible] [illegible] [illegible] [illegible] surrounding all.

The ileum, Fig. 75, has the same layers, the "Härchensaum" being [illegible] by a thin chitinous cuticle, showing this portion of the digestive tract [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] and is very noticeable in the sections. The circular muscles do not follow the infoldings of this membrane but leave spaces at those points.

[illegible]

the inner circular muscles of the ileum.

The rectum Fig. 70 has its epithelium thrown into many and pronounced folds. The cells are tall, columnar with very indistinct boundaries and with the nuclei near the bases of the cells. The epithelium [illegible] greatly in appearance from that of the stomach. The basement membrane follows all the folds of the epithelium and [illegible] muscle fibres ramify over it in all directions. The chitinous intima bears a few small, short spines.

The salivary glands open into the pharynx just in front of the [illegible] in a median duct which leads back, close beneath the [illegible] [illegible] [illegible]

The duct is lined by a chitinous cuticle.

The Malpighian tubes, Figs. 71, 77, are long convoluted tubules which arise from the digestive tract close to the junction of stomach and ileum. Their number is not determined. [illegible] found [illegible], [illegible] [illegible]

[illegible] in his diagram of the digestive system of Lepisma represents but three. From what he says however, I infer that he regards the number as variable. I have been unable to ascertain the number in the examples which I have examined, but feel certain that there are at least four.

The tubes each consist of a single layer of cells with the walls rounded externally and internally (Fig. 77) and none visible between neighboring cells. The nuclei are quite large, round or oval, and scattered through the epithelium [illegible] secretive granules [illegible] also occur in the lumen. The protoplasm of the cells stains quite deeply. Whether there is a chitinous intima lining the lumen, or not I cannot say.

Fat Body.—

The histological appearance of the fat body is much the same in Lepisma as in [illegible]. Its distribution is not so sharply defined however, and can be best described by saying that it occupies almost the entire body cavity, while through it pass muscles, nerves &c. Its relation to the hypodermis [illegible] also to be much as in [illegible] except that where the two are contiguous there may sometimes be observed what is

appears with a delicate basement membrane as in other tissues, Fig. 78.

[illegible]

The heart is situated as in Thysanura on the dorsal median line, and extends forward from that portion of the abdomen where the ileum bends [illegible] smaller and, as the aorta, continues to the prothorax where it bends down and comes to lie close above the oesophagus. When it has reached a point dorsal to the subœsophageal ganglion it becomes lost. The histological structure of [illegible].

The posterior end of the heart instead of forming a rounded closed end [illegible] for one or two blood corpuscles to lie in, side by side, while its walls become very muscular (Fig. 79). This portion of the dorsal vessel soon becomes attached to the dorsal hypodermis, and finally, near the base of the median anal stylet opens with a flaring mouth like that of a trumpet, into the body cavity. Near this point it is surrounded and firmly held in place by numerous bands of muscles leading from the dorsal body wall to a median diverticulum of the rectum lying just beneath. One or two of the more median of these muscles appear to

[illegible] the ventral side of this bloodvessel and become attached to the hypodermis again thus placing it in a sort of sling. Figures 79 and 80 represent sections of this bloodvessel and of the dorsal organ drawn [illegible]

I have met with no description of the posterior portion of the dorsal vessel which agrees with what I have just described, and long doubted the accuracy of my observations. The same thing occurring in all my specimens, however, and the confirmation of the above description [illegible] neither an individual variation, nor the result of a too hasty examination, but that it is a normal feature in this animal. As to its function I can only suggest that as it is highly muscular and near the posterior end of the body it may be the chief contractile portion of the vessel.

The blood corpuscles, Fig. 80, apparently differ in no way from those of [illegible].

Tracheal System. —

A tracheal system is present but owing to a lack of material for special examination on this point I can say but little of it.

The stigmata open into tracheae which have a chitinous intima, with delicate spiral threads. The tracheae run chiefly in a longitudinal direction and with but little branching. Almost any anterior section of the abdomen will show two trunks cut transversely, lying quite near the lateral surface of the body.

Nervous system.—

The nervous system comprises a brain or super-oesophageal ganglion and a sub-oesophageal ganglion united by a circum-oesophageal commissure, three thoracic and eight abdominal ganglia. The two first mentioned ganglia are situated in the head; the last thoracic and first two abdominal ganglia are fused together (Fig. 81), and the seventh and eighth abdominal ganglia are also fused (Fig. 82). From the brain the antennae and eyes are innervated, and from the sub-oesophageal ganglion, the different mouthparts.

Histologically, the brain shows many features of resemblance to the brain of the cricket, Fig. 83. But I shall not attempt a description of its parts. No trace of giant cells near the commissure [illegible] [illegible] [illegible] [illegible] [illegible] [illegible].

Sense Organs.—

The only sense organs which I have observed are the tactile organs and the eye.

Tactile Organs: These differ little from those of Anurida except that at their bases there appears to be a distinct joint with the cuticula (Fig. 75) which resembles those similarly located in higher insects.

The bristles are scattered over the entire body, but are especially abundant on the head. The long and slender antennae and the three anal cerci which contain no muscles, have each a nerve fibre and are true tactile organs. No such trilobed organ as that described in Anurida was found.

Eye: The eye is not "an aggregation of ocelli," but is a true compound eye, directly comparable to that of other Arthropods, and very different from that of Anurida.

Each is composed of twelve ommatidia which form a cluster of a pyramidal shape, in consequence of the [illegible] (Fig. 84). The external facet — the cornea — of each ommatidium is large, and immediately beneath it are two large cells which [illegible] the corneagen. These cells are [illegible] at the [illegible] of the ommatidium than at the periphery and are therefore somewhat [illegible] in section

Just internal to the corneagen is the crystalline cone, which is a large concavo-convex mass of chitin nearly filling the entire ommatidium at that level. Just external to it and filling the space remaining at its [illegible] are four small cells constituting the vitrella. Filling the inwardly facing concave portion of the crystalline cone, and passing inward, is a rather long pyramidal chitinous mass — the rhabdomere. Immediately surrounding this, and prolonged beyond its tip are [illegible] [illegible] pigmented cells forming the retinula. The prolongations of these cells perforate a basement membrane just internal to the group [illegible] and [illegible] [illegible] [illegible] [illegible]

Surrounding each ommatidium and filling in [illegible] [illegible] [illegible] [illegible], is a mass of small pigment cells.

If the parts of an ommatidium be pushed away from the central axis in all directions the outer layers moving most, while the retinulae retain their natural position a pit is formed. If this arrangement is projected onto a plane [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] of the retinulae are left without the pigment and the chitinous portions of the two outer circles are represented as narrow bands and [illegible] [illegible] [illegible] [illegible]

This description of the eye is in harmony with the recent [illegible] [illegible]

to the origin of the compound eye offered by Watase, ('90) to whom I am indebted for many suggestions and from whose paper I obtained the idea of the method of representation used in Fig. [illegible]

In some regards the ommatidea [illegible], [illegible] as figured by Watase, ('90) and appear to form one of the simplest compound eyes yet described among the Tracheate Arthropoda.

No trace of any post-antennal organ occurs.

[illegible]al Organs.—

The position of these organs and their histological structure is nearly the same as in Anurida, and because of this I will here [illegible] Grassi ('87a) showing their position and form in the adult male, Fig. 86 and young immature female, Fig. 57). These figures do not represent the portions of the ducts which are of epiblastic origin.

General Considerations.—

[illegible] than Anurida. This is [illegible] the presence in the former of an ovipositor, scales, well developed mouth-parts, Malpighian tubes, a [illegible]

muscular portion of the heart, a tracheal system; by the modifications of the different portions of the digestive tract and the histology of the brain and eye.

[illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] absence [illegible] this [illegible] in the adult, [illegible] great simplicity of the mouthparts and entire alimentary canal, and by the total absence of tracheae. These modifications however, [illegible]

Existing Views as to the Relationships of Arthropods.

This portion of my subject has been prepared from material collected from so many sources that it is impossible to give the exact references for each statement. A list of the literature examined, however, will be found at the end of the article.

The division of the Arthropoda into Crustacea and Tracheata is one that has long existed. The latter consists of three large groups — Hexapoda, Arachnida and Myriapoda — and a number of smaller ones, and the various views expressed as to the relations of these subdivisions have [illegible] authors [illegible] Tracheata might be accepted as a natural group, the general opinion being that the group was by no means to be accepted as a natural one

Haeckel ('66) advanced the view that all the Tracheata originated from a common ancestor — some primitive Crustacean which he termed the Zoëpoda; a view already suggested by Fritz Müller ('64).

[illegible]

[illegible] stem very early in its development. This is the so-called [illegible].

More recent studies have resulted in the promulgation of another view — that the insects and myriapods had a common but far [illegible] which were also developed the two branches of Crustacea and Arachnida and which was itself derived from some [illegible] form.

Before considering these and other views more fully, let us ascertain the prevailing opinions as to the relations of the smaller groups [illegible].

Limulus is no longer a form of doubtful affinities, the works of Lankester, Kingsley and others having pretty conclusively demonstrated its close relation to the Arachnids and especially to the Scorpions. [illegible] The former is regarded as a branch of the stem from which the [illegible] the tip.

The Pycnogonida were at first regarded as Crustacea, and later as Arachnida. The researches of Dohrn '81 have led him to the belief that they are entirely independent of all the other groups of Arthropods. Schimkiewitsch '84, '87 on the other hand regards them as both primitive and degraded forms but having

common ancestors with the Arachnida, and Kennel[?] also seems the same view.

[illegible]

but Zudemans ('85) believes that they should be removed altogether from the Arthropoda and placed among the fresh-water Chaetopod worms. Plessenborn ('87) from a study of their dermal skeleton and appendages [illegible] before the Arthropod branch. On the whole, the phylogenetic position of this group may be considered as uncertain.

Of the groups of the Arachnids — the Araneida, Acarina, Phalangida, Pedipalpi, Scorpiones, Pseudoscorpiones, Solpugidae and Pentastomida — the position of the latter group is doubtful, showing as it does, many features similar to those of the Myzostomida (Balfour '80.). Schimkewitsch ('87) however regards the proposal to remove them from the Arachnids and place them with this group as unwarranted.

As to the other groups mentioned the general opinion is that all are derived from a common Arachnid ancestor (Zudemans '85) [illegible] from this, however, regarding the Araneida and Acarina as [illegible]

Arthropod stem.

Peripatus is in many features worm-like; in others Myriapod affinities are suggested, while still others appear to point to an independent origin. It is generally placed near the Myriapods and Insects, however, and is considered to be a very primitive form.

Passing now to the larger groups, the phylogeny of the insects is a problem presenting much difficulty in its solution. That portion of the view of Haeckel ('66) which concerns the Insects — that an aquatic Zoea-like form assumed a terrestrial habit and acquired a tracheal respiration — is, for reasons which will presently appear, unsatisfactory.

Another theory — the "Campodea Theory" — has been advanced by Brauer ('69), Lubbock and Packard. This assumes that the [illegible] air-breathing larva (campodeaform or leptiform larva) is an indication that the earliest insect had a similar structure. The caterpillar and grub (eruciform larva) are secondary adaptations, according to this view, and the Thysanura are the most accurate representatives of the ancestral form, of any insects now living.

The derivation of this form is not agreed upon by the supporters of the Campodea Theory. Meyer ('76) believes it to have arisen from

some unjointed worm, which formed a point of divergence for all Tracheates and the higher worms and closely related to a form which was the ancestor of the Crustacea. Brauer ('85) regards the Insects as derived from a form in which development of the appendages of the first three post-cephalic segments, and retrogression of those of the other segments occurred. From this modified form, through the multiplication of homonomous segments, the Myriapoda branched off on one side, and the insects (Apterygogenea (primitively wingless insects) on the other. Lubbock ('7.) inclined to trace the Thysanura back to the Tardigrada and through them to the Rotifera, while Wood-Mason and Grassi (Haase, '8.) derive them from the Crustacean Nauplius or Zoea. Several slight modifications of these views are held by various students of the subject.

A third theory has also been advanced, chiefly by Eigenmann ('9.). He regards the ancestors of insects as aquatic, breathing by a row of metamerically placed tracheal gills on each side of the body, as is seen in the larvae of Ephemeridae at the present day. This form developed from a worm bearing dorsal gills. As this worm for some reason became terrestrial, the pairs of gills on the mesothorax and metathorax became greatly enlarged and functional for locomotion, while the others became worn off, leaving an opening

where the tracheal trunk passed from each gill into the body, as representative of the stigmatal opening.

Something not unlike this is found in the writings of [illegible] the [illegible]: The wings of Insects are branchial laminae [illegible]

[illegible]

[illegible]

[illegible]

a higher function, in correlation with a generally transmuted state of the rest of the organization which is advanced to the [illegible] susceptible." The same general conclusion is also reached by Plateau, '71.

This view is a most pleasing one, offering as it does such [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

while the earliest fossil remains are those of [illegible] forms closely resembling the Orthoptera Blattidae. [illegible] in the same

of tracheal gills as an ancestral feature is overestimated, for in some species precisely similar gills occur on the joints of the legs, the ventral surface of the body, and even between the wings. As these cannot correspond to the tracheal gills of worms, and as tracheal gills of any kind occur in so few forms, the suspicion arises [illegible]

Examining now the various views as to the relation of the Myriapods to the other Arthropods, we find a great hesitancy on the part of the more recent writers to express their opinions. Placed by all the earlier students of the group, as an offshoot of the hexapodan stem or even as the direct ancestors of the Hexapods, views opposed to these have been [illegible] cautiously expressed and then qualified by statements that too little [illegible] known of their anatomy and development to warrant a discussion of the question. Heathcote ('88) states however, that he regards them as being remotely descended from some Peripatus like stock, but says nothing as to their relations with the Hexapods. Packard ('83) believes that the Myriapods branched off from a much more primitive form than [illegible]

[illegible] voices a growing idea among recent workers when he says: "it seems possible that they [the Myriapods] have no connection with the Hexapods."

Peripatus seems to be nearer to the Myriapods than to any other group, and it may be that these are derived from a common ancestor wholly distinct from that of the Hexapods.

A consideration of the relations of the various groups is best accomplished by an examination of their stem forms. When these are not in existence their characters may be ascertained in part in three ways — from Paleontology; the anatomy of their descendants; and the Embryology of these. In the examination of these sources of evidence all secondary and recent acquirements, all falsifications of the record, precocious development, coenogenetic and all modifications must be considered. Difficult as the task is it is rendered far more so by the terrestrial habitat of the Tracheata, for geological [illegible] would [illegible] far more frequent and extreme changes in a terrestrial than in a marine environment, these changes [illegible] of [illegible] significance in the struggle for existence and the survival of the fittest. It is not to be wondered at therefore, that the various views offered in the past have differed greatly in many regards, and any suggestions offered with our present knowledge, should be only tentative.

The evidence afforded by paleontology is as for other groups very fragmentary. Scudder ('8[illegible]) says: "The earliest insects then were generalized hexapods, Palæodictyoptera, in which the four wings were equally and simply developed, membranous, and with very simple [illegible] [illegible] were simple and 'incomplete,' the young leaving the egg in the form of the parent but without wings, [illegible] maturity. They appeared probably as early as any land plants, certainly by the middle of the Silurian epoch, and continued as a homogeneous type until the end of the Paleozoic period."

In [illegible]ozoic times active differentiation occurred, the modern [illegible] [illegible] the Diptera, Hymenoptera and Lepidoptera appeared last, in the Lias and Oolite. Since the Tertiary epoch little change in the general features of the insect life has occurred.

Brauer ('86) regards this view of Scudder's as incorrect. Instead, he thinks that the paleontological evidence shows that Paleozoic Insects do not contradict the ordinary belief of a Thysanuran-like ancestor, nor do they form a special order — [illegible]

[illegible]

proof can be advanced for the group Palaeodictyoptera.

Thus the chief facts derived from this source of evidence are that the oldest known Insects were structural with four similar wings, incomplete metamorphosis and that they were already quite highly developed in very early times.

Thus far Palaeontology [illegible] evidence afforded by Anatomy and Embryology.

Features universal among Insects [illegible] differing modifications in connection with differences of food, habits, environment and the like may be considered [illegible] fundamental value [illegible] to determine the [illegible] of the Hexapoda these universal features must be collected.

Excluding the [illegible] from consideration [illegible] characters present in all adult Insects.

I. The body is segmented and bilaterally symmetrical. Division into head, thorax and abdomen is also an almost universal feature. A pair of jointed legs is present on each thoracic segment. Abdominal legs are absent in the adult. In the embryo [illegible] a pair of processes appears on the ventral surface of each abdominal segment. These afterwards disappear, and some of the second

sexual appendages of the abdomen are regarded by some as being derived from them. The presence of wings or of dorsal [illegible]

On the head occur a pair of jointed antennae and a pair of eyes. The mouthparts differ much in the different orders, but may all be reduced to modifications of a mandibulate type, with three pairs of jaws and that this condition is the more ancestral is indicated by what embryological evidence we possess.

Exceptions to some of these statements occur, but in every case the reason for the exception can be shown to be secondary adaptation, which does not invalidate the statements above.

II The external covering consists of a chitinous layer, secreted by a subjacent cellular layer. Scales and hairs (except sensory hairs) are not ancestral.

III The digestive system varies much in the different groups, the [illegible] and habits. [illegible] a duct passing from it to the main alimentary tract, or [illegible]

as to form a series of chambers serving a similar purpose. Those Insects with comparatively innutritious food have long and convoluted alimentary tracts, with various valvular structures to aid in extracting nourishment from the food, while insects in which the food is more concentrated have simpler digestive organs.

The universal features of the alimentary canal are partially indicated by Embryology. From a study of its development we conclude that a median portion is derived from the hypoblast (mesenteron) and that this portion acquires communication with the exterior by means of two invaginations of the outer surface, the anterior one the anterior stomodaeum and the posterior proctodaeum. These unite in each case with the mesenteron, all together forming a continuous tube. The lining walls of the two invaginations preserve their ectodermal property of secreting a chitinous outer layer, which is evident in the adult. By modifications of these three parts of the alimentary canal the many different structures seen in different insects are obtained.

Quite universal is the presence of a pair of [illegible] at the [illegible] [illegible]

[illegible]

imagination. While these may possibly be modifications of another set of structures, they apparently assumed their present functions and position at a very early period of Insect phylogeny, and may fairly be regarded as quite ancestral.

IV. The body cavity is at least partly filled by a fat body, in [illegible] of which a condition [illegible] occur.

V. The respiration [illegible] [illegible]

or otherwise secondarily adapted forms. Whether tracheae leading to open stigmata, or into closed gills, is the ancestral condition, is a much controverted point which will be considered later. That a tracheal system of some sort is an ancestral feature, however, there can be no doubt, nor that these tracheae were present in pairs in the thorax, and in the anterior (perhaps all) segments of the abdomen.

VI. The circulatory system in Insects varies little. It consists of a dorsal vessel or heart, which becomes contracted in the thoracic region forming a smaller tube—the aorta. This was probably very nearly its ancestral form.

VIII. The nervous system of the Hexapods has certain features common to all groups. These are a ganglionic mass above or anterior to the oesophagus — supraoesophageal ganglion or brain — connected with a similar ganglionic mass posterior to the oesophagus — infra- or sub-oesophageal ganglion — by two nerve cords, one passing each side of the oesophagus which is thus surrounded by a ring of nervous matter. The two nerve cords constitute the circumoesophageal commissures. Posterior to the infra-oesophageal ganglion is a series of similar ganglia connected to each other by two commissures. Comparison of the nervous system in different insects and in different stages of development indicates that the ganglia while showing a [illegible] [illegible] a metameric arrangement, one for each segment of the body, show also a tendency to concentrate towards the head and fuse with one another. Resulting from this, the number of ventral ganglia varies in different Insects. Similarly, some Insects have ganglia which are dense rounded masses of nerve cells and fibres; in others they show traces of having been at some time two ganglia side by side, and in still others the fusion is even less complete.

Thus we may assume as primary two parallel bands of nerve cords with an enlargement in each band anterior and another posterior to the oesophagus and one enlargement in each of the remaining segments of the body. Probably the two ganglia anterior to the oesophagus had already fused to form the super-oesophageal ganglion. The suboesophageal ganglion is probably the result of the fusion of the ganglia of several [illegible] at a very early period.

VIII. Insects are always unisexual. The essential organs are paired or show traces of modification from such a condition [illegible] (certain exceptions do not affect this general statement). The [illegible] and have no phylogenetic value, being comparatively [illegible]

Some of these points demand a fuller consideration. The question [illegible] mouth is one of much importance for if it can be shown that the Arthropod head consists of a series of much condensed

and modified metameres only, it will aid in establishing certain views as to the phylogeny of the group, to be considered later.

Everywhere among Arthropods we observe marks of metamerism which in the thoracic and abdominal regions is almost wholly undisguised. We find that these regions consist of a series of similar segments showing much the same structure, both as regards the skeleton and the internal anatomy. Each segment bears a pair of ventral appendages; each has a nerve ganglion, and the [illegible] of a segment are innervated from the ganglion of that segment. In the Insects the thoracic appendages are [illegible] greatly developed; with the abdominal appendages on the contrary it is the reverse, and their existance is now shown chiefly by embryology.

A study of the mouthparts shows that they are ventral appendages which [illegible] common [illegible] of their number and innervation should throw some light on the [illegible] value [illegible] region [illegible] the head [illegible] the amount of cephalization and condensation it has undergone, and of what it [illegible]

In side view the supra-oesophageal ganglion of Insects shows three enlargements. The anterior one, called in Dallance "S"

the Protocerebrum gives rise to the nerves which innervate the eyes.

[illegible]

while the third — Tritocerebrum — which in the Decapod Crustacea innervates the second pair of antennae, here innervates no appendages but gives rise to the roots of the stomato-gastric "sympathetic" system. On this segment is borne the Labrum or upper lip. This is not [illegible] portion of the ventral integument. Passing to the suboesophageal ganglion we find that it innervates the mandibles, maxillae and labium, indicating that it is the product of the [illegible] view of Viallanes must be accepted, and the head be considered as [illegible]

[illegible] disputed points. The view of Gegenbaur ('70) already briefly stated, is that the open system with stigmata is secondary, the primary condition being a closed system leading into a pair of lateral, leaf-like expansions on the sides of each segment. The air in the tracheae in these [illegible] these insects lived, and by a gaseous exchange that within the

tracheae was justified. He believes that the tracheae originally functioned as hydrostatic organs and became secondarily adapted to their respiratory function, developing for its furtherance the initial [illegible] hypertrophied upon a change to terrestrial life, while the remaining ones became lost at a subsequent molt of the cuticle leaving open [illegible].

[illegible] arguments to support it is that larvae which will later have [illegible] have no stigmata on those segments. If by the theory the wings are hypertrophied tracheal gills, stigmata should not occur on those [illegible] which have mesothoracic stigmata. Another difficulty has [illegible] stigmata will open in the adult and though stigmata and gills never coexist in a segment, yet the point of attachment of the gill never coincides with the place where the future stigma will open. He urges that the gills and stigmata have no genetic relation and

that the closed tracheal system is secondary.

[illegible]

processes appear, into which the tracheae grow at a distinctly later [illegible] should contain tracheae from the first, as according to that view the processes are developed to satisfy the demand for the purification of the air in the tracheae. From his studies on the subject, [illegible] thinks that the wings are not modified tracheal gills, but regards them as derived from lateral processes of the dorsal plates of the segments concerned.

The evidence from rectal gills in the larvae of the Libellulidae [illegible] as being secondary, and correlated with the assumption of an aquatic habit. [illegible] metameric external gills are also secondary acquisitions, and other facts seem to sustain this view. Hence the assumption above, that the primitive form of respiration was through open stigmata and that the forms possessing it were terrestrial, is not contradicted by the facts.

The absence of stigmata on the head and on one or two abdominal segments remains to be considered in this connection. The view [illegible] of [illegible] [illegible] that each organ segmentally repeated in some segments should be present in some form in every segment. To find traces of the missing stigmata and the tracheae leading from them embryological investigation has been resorted to and in some cases [illegible].

For the lack of stigmata on certain abdominal segments, the description of the development of the Bee as detailed in Grassi ('84.) may be considered. He says that on the posterior region of the dorsal surface of the embryo two little pits are formed. Later, the area containing them becomes invaginated to form the proctodaeum and elongation of the pits converts them into the two pairs of Malpighian tubes of the adult. The only difference between these pits and those of just developing tracheae is that the former are [illegible] smaller than [illegible] the abdomen were not folded onto the dorsal surface of the egg the pits would exactly correspond. He claims additional value for this explanation from the fact that in the silkworm stigmata are

absent from three segments, and there are three pairs of Malpighian tubes in the adult. On the other hand Cholodkovsky ('87) states that the larval Malpighian tubes of each side, normally three in number, join the proctodaeum by a single basal trunk. In the pupa the terminal portions undergo histolysis and are ultimately lost, while the basal trunks grow out to form the Malpighian tubes of the adult, remaining simple (Tineidae) or branching to form three tubes on each side (most Lepidoptera).

If these observations be correct the primitive condition in Lepidoptera was that of a single pair of Malpighian tubes and therefore representing the segmental [illegible] of but one segment.

If we seek for modified excretory organs in the head we find no structures which can be homologised with them in any part of the pre-oral portion. Homologous structures are evidently present in some of the post-oral segments however.

Two organs may be considered in this connection — the salivary and the spinning glands. The former arise as paired epiblastic invaginations of the ventral plate just behind the mouth, on the inner side of the mandibles. The ducts are lined by chitin which shows markings very similar

to the delicate spiral threads so characteristic of tracheae. The generally accepted opinion is that the salivary ducts (and probably the glands) represent the tracheae of the mandibular segment of the head.

The [illegible] of the salivary glands [illegible] more apparent. They are present according to Claus ('85) only in larvae, but more recent researches have established their presence in the adult Tenthredineae (Poletajew '85) and in embryonic life Grassi ('86) has described in the Bee three pairs of epiblastic pits corresponding to the three buccal segments. That one well developed pair of salivary glands [illegible] already stated in larvae is well known. They exist as epiblastic invaginations on the inner side of the second maxillae (labium) in Apis and Lepidoptera according to Balfour ('80) and are very similar in their structure and development to salivary glands.

These facts indicate that salivary glands which at present are in some larvae have become rudimentary and only perceptible in the embryonic life of the majority of Insects. The three pairs of pits observed by Grassi would indicate the presence of a maxillary pair of tracheae which have become even more rudimentary than the

labial pair. It would be interesting however to study the development of the salivary reservoirs, to determine whether they are diverticula of the salivary ducts, or derived from maxillary invaginations which have acquired a secondary relation to the mandibular pair.

Thus we find at some stage of development, traces of structures homologous with antennae and [illegible] in each of the post-oral segments of the head. Their absence on the preoral portion, and the presence here also of similar appendage rudiments in the same segments [illegible] while it is possible that the preoral portion is itself a fusion of several (three) segments, it is also possible that these segments are not homologous with the post-oral ones. What may perhaps be interpreted in the same way is the absence of nephridia from the three anterior somites of the body of the Diplopoda.

The primitive arrangement of the genital ducts comes up for consideration. The almost universal unpaired condition in the adult forms is an exception in the Chilognatha where the ducts are distinctly paired as has been shown by [illegible]. Considerable embryological evidence also indicates a paired arrangement as being the primitive one. Without entering into details on this topic, suffice it to say, that it is probable

that the genital organs and ducts were primarily distinct from each other throughout.

If from this summary of the ancestral features retained in the insect [illegible] we attempt to [illegible] the [illegible] of the primitive [illegible] from which they have been derived and which has been named [illegible] by [illegible], we shall [illegible] the [illegible].

Archentomon was a segmented, bilaterally symmetrical animal, showing a division into head, thorax and abdomen perhaps slight; a pair of jointed legs was present on each thoracic and abdominal (?) segment; two pairs of wings, perhaps only dorsal lobes, were present on the last two thoracic segments: a pair of antennae and a pair of eyes were borne on the head: the mouthparts were formed for biting, and three pairs were present.

The body was covered by a somewhat chitinous layer resting upon a cellular layer: the alimentary tract was a straight tube, the terminal portions of which were lined by a chitinous layer like that of the surface of the body: into the anterior portion of this tube opened the ducts of a pair of secretory glands, and into the posterior portion [illegible]

effected by tracheal tubes opening to the exterior one pair in each thoracic and abdominal segment except one or two of the latter. The circulatory system consisted of a dorsal vessel [illegible] in the thoracic region. The nervous system consisted of two fused anterior ganglia, forming a supraoesophageal ganglion; two nerve cords, one passing each side of the oesophagus and entering a suboesophageal ganglion consisting of several ganglia fused; posterior to this, a segmentally placed series of ventral ganglia joined to those next in front and behind by pairs of commissural bands. A fat body at least partly filled the body cavity. The sexual organs were paired and opened to the exterior by a median duct. The sexes were distinct and the [illegible] was [illegible].

Having now obtained some idea of the probable structure of the earliest Insects, we are prepared to consider the relations of the Thysanura to these forms.

If we inquire into the cause of simplicity in some members of a group of in general high complexity, we find that the simplicity may result from the action separately or together, of a number of influences [illegible] features, the animals concerned entering but slightly into the

[illegible] [illegible] [illegible]

circumstances which have changed but little (as with Limulus), or it may be the result of degradation. If the latter be the case, the degradation may be the result of a parasitic life, or of a change from a motile to a fixed life, as in the barnacles (Cirripedia), or it may be correlated with a change of habit and surroundings.

Restating these possibilities for the case in hand, and excluding degradation resulting from parasitism and from an attached life, as not here applicable, we obtain the following: The [illegible] and the Insects are derived from a common stock.

a. Both groups have undergone much differentiation, but in the Thysanura this ceased after a time and was followed by degradation, resulting in the production of forms so simple as to appear primitive. b. [illegible] much differentiation the Thysanura have from some influence varied little and have retained most of their ancestral features.

[illegible] concerning the Thysanura be correct [illegible] should show [illegible] [illegible] It [illegible]

[illegible] ancestors but that little change as to outward form as the [illegible] a constantly increasing differentiation while the embryo leaves the egg when it is nearly like the adult.

[illegible] of the same reasoning that [illegible] are [illegible]

[illegible] of [illegible] primitive forms.

With the Collembola the case is somewhat different. To many features common to both groups are added others suggestive of a greater amount of differentiation. Thus we find a [illegible] of the nerve cord: the presence of various well developed [illegible]

[illegible] the absence of tracheae and the [illegible] condition of the mouth parts all indicate degradation. The general [illegible] drawn from a consideration of these facts is that the Collembola

is a group in which greater differentiation has occurred than in the Cinura, followed however in some cases by a [illegible]tation.

[illegible]

Campodea theory is sustained, on the one hand by the evidence obtained from the higher insects, an[illegible] anatomy of the Thysanura. Of the latter group, the [illegible] are less complicated on the whole than the Collembola and Campodea and Japyx are among its simpler members while Lepisma and Machilis are more highly developed.

[illegible]

From Archentomon two or several trunks develop. One of [illegible] trunks divides, one limb becoming the Cinura which have [illegible]

Hence the branches of this limb would be short, the con[illegible]nes representing Lepisma Machilis &c., while the tip of the limb [illegible]

[illegible]

Some of these branches however, soon bend back toward the trunk which all diverge but little after the first.

The other main trunk or trunks develop rapidly and in different directions and represent the different orders of the [illegible] cannot here be discussed.

For years the Campodea theory rested at this point. Attempts to trace relationships with the Crustacea, Tardigrada, Myzostomida and other groups were made, but no results of value were obtained.

Ryder ('81) however, upon examination of Scolopendrella a [illegible] to the conclusion that it should be regarded as the type of a new order of Articulata, for which he proposed the name Symphyla. This form has come to be considered by many, as the probable [illegible] of the group of animals from which Archentomon was descended, while in our systematic works it is included among the Thysanura as a [illegible]. It "may indeed be looked upon perhaps as representing the last survival of the form from which insects may be supposed to [illegible]

This view is at first sustained in part, by the anatomy of Scolopendrella. The animal is composed of a head and thirteen body segments each bearing a pair of legs. the head is flattened; the [illegible] end in a pair of claws as in Insects: the genital opening is [illegible] resemblances to the Thysanura, have led to a suit [illegible]

Let us now consider the Myriapods with reference to [illegible]

[illegible]

of the latter into thorax and abdomen. In this respect Scolopendrella approaches the Thysanura rather than the Isopods. In the internal anatomy of the Diplopoda [illegible] the [illegible]

[illegible]

indication of thoracic and abdominal division but external anatomy fails to furnish any evidence to confirm this view.

Perhaps the most noticeable distinction between the Myriapods and Hexapods is that expressed in the names of the groups. Those persons who have attempted to derive the latter from the former have laid stress upon the presence of abdominal appendages [illegible]

where they are regarded as having been retained for some reason in the adult, though absent in this stage in the Insects. The presence of two pairs of legs on most of the segments of the Diplopoda has also been called attention to as indicative of a [illegible] increase in the number of segments and thus explaining the divergence in the number of these in the two groups. [illegible]

[illegible]

[illegible]

of a partial fusion of two which were originally distinct from each other.

Recent studies by Heathcote, '88, on Julus show that the nerve cord, tracheal and circulatory systems and the segmentation of the mesoblast indicate [illegible] segments are the dorsal plate and the setae glands. Heathcote considers each part as representing a distinct segment but joined to its fellow by the fusion of the dorsal plate.

[illegible]

[illegible]

[illegible] abdominal appendages serving a [illegible]. What this function may have been is

uncertain. Natural first thought it would be that they were true legs; but the form of the limb on the first abdominal segment is sac-like or leaf-like and gives not the slightest indication of a [illegible] possibly the result of a secondary modification of this pair of appendages. If not, the view that they were legs must be abandoned and [illegible] which case the appendages might be regarded as gills.

[illegible] the abdominal appendages of the Thysanura is next in order. This has recently been accomplished by Haase ('89) who finds small abdominal processes in the Cinura, Collembola, Symphyla and in a few Insects. The conclusions which he [illegible] abdominal appendages: that these became rudimentary and in [illegible] cases entirely disappeared. The present existing abdominal appendages of the Thysanura he regards as not homologous with those [illegible] die beweglichen Griffel nicht als Rudimente von Beinen sondern nur als diesen analoge, aber nicht einmal homologe

[illegible]

einiger Hinterleibssegmenten auf den noch deutlich vorspringenden Extremitätenresten zurückzuführen wären." Supporting this is a statement in Lindemann's [illegible] of which the details are as yet unpublished, that Thermophila furnorum one of the Lepismidae, which when adult has a pair of "exsertile" appendages on the ventral sides of [illegible] [illegible] in immature specimens. The hindermost pair appear first then those of the eighth segment, and finally the anterior pairs. [illegible] [illegible] [illegible] rudimentary, and that they have nothing to do with true abdominal legs. Another consideration is that if homologous with the abdominal appendages of Insect embryos they [illegible] [illegible] In other words the tendency of a character to appear earlier and earlier in ontogeny [illegible]

stage at which these [illegible] appear in Insects and the adult condition as seen in forms differing in no greater degree than do [illegible]

Another feature worthy of consideration in this connection is the embryology of the Myriapoda. [illegible] Metschnikoff shows that in this group the larva emerges from the egg [illegible] post-embryonic [illegible] pairs of well developed legs. Additional segments and appendages develop as post-embryonic changes. If we compare this process with that in Insects we find a radical difference. In the Insect [illegible] before hatching rudiments of appendages appear to the number of ten pairs upon the abdomen (Lepidoptera) aside from the three thoracic pairs also present. After hatching instead of an increase in the number of segments, either no change occurs, or [illegible] — [illegible] — [illegible] become lost before the hatching takes place.

Another difficulty is met with in [illegible] appendages of the head and thorax in the two groups, and [illegible] point I quote Moseley ('84) who says: "The young Strongylosoma [a Diplopod] has three pairs of functionally active legs: the young [illegible]

somites being apodous, and it was formerly thought this fact established a connection between the Myriapoda and the insects, the three pairs of larval legs of the Myriapod being supposed to correspond with the three pairs of legs of insects. Such, however, is not the case, there being no second maxillae in Myriapoda the first pair of legs in the larva must correspond with the second maxillae of insects; and even if this could be shown to be incorrect the three pairs of legs would still not correspond with those of insects because in the young Strongylosoma the second, and in Julus the third post-cephalic somites are devoid of legs. Moreover the larvae are only apparently hexapodous, not in reality so. In Campodea there is a hexapodous larval stage, in the Myriapoda no functional or real hexapodous larval stage occurs as far as is known.

The mechanism of respiration in the Myriapoda has been investigated by Charlande ('87) and found to differ entirely from that in the Hexapoda, for in the former group no dilatations or contractions of the body cavity, capable of causing respiration, were [illegible] place; neither the [illegible] [illegible] movements [illegible] relation to respiration, the stigmata being

wholly passive. In repose inspiration and expiration are [illegible] in motion this is aided by the action of the muscles on the tracheae. [illegible]

In the Myriapoda the antennae are innervated from the brain anterior to the portion innervating the eyes, according to Newport ('43.), but in the Hexapoda according to Kingsley ('85.) a different arrangement apparently exists. My own researches fail to confirm this last statement, for the Thysanura at least, and the whole subject needs re-examination.

These differences are so great, both in number and in amount that a close relationship of the Myriapoda and Insecta appears doubtful, and the position of Scolopendrella becomes more uncertain. We may conclude that the weight of evidence negatives any close relationship [illegible] [illegible].

Turning now to Peripatus, we find as in the Myriapoda no division into thorax and abdomen, and that the body is a repetition of similar metameres, each with a pair of appendages. The head bears a pair of jointed antennae, the mouth is armed with a

pair of jaws and is followed by a pair of papillae on which open the ducts of a pair of slime glands.

Without attempting a description of the anatomy of this [illegible]

In the Insects we have three pairs of mouth-parts; in the [illegible]poda three; in the Diplopoda two; and in Peripatus a single pair. The number of pairs of antennae is the same throughout. The nervous system of Peripatus is unlike that of any other known Arthropod. The super-oesophageal ganglion is formed by the fusion of two masses as in the other Arthropods, but the two halves of the ventral nerve cord, instead of being fused and situated on the median line, lie quite far from each other and are connected by numerous cross commissures, giving the entire structure a ladder-like appearance. At the posterior end the two cords bend dorsally and unite above the rectum. The sexual organs open to the exterior near the [illegible] end of the [illegible] by a median [illegible]. In the Diplopoda the sexual organs form a single median mass opening to the exterior upon the coxal joints of the second pair of legs, by a pair of ducts. In the Chilopoda

organs are unpaired and open by a single duct at the posterior end of the body. The arrangement in Insects has already [illegible] condition [illegible]

In their development the species of Peripatus are very anomalous and differ greatly. In three species Sclater ('85) found no yolk and a total segmentation; in P. capensis there are indications of a recent loss of yolk, and the segmentation is total or meroblastic, while in P. novae-zealandiae there is a great deal of yolk and the segmentation is meroblastic. In P. capensis gastrulation is shown by Sedgwick to be epibolic. The elongation of the blastopore and its division result in the conversion of one part into the mouth and the other into the anus of the adult. [illegible] a different one.

One feature of the tracheate Arthropods is the possession of [illegible] their function is performed by segmental organs comparable to those of the Annelids, a pair of which occurs in each of the [illegible]

the [illegible] [illegible] not [illegible] the mouth. [illegible]

[illegible]

[illegible] opening near the posterior end of the body, the conclusion appears to be forced upon us that these glands are not homologous [illegible]

[illegible]

[illegible] to the studies on the development of [illegible] points [illegible] resemblance to Peripatus and in conclusion remarks that [illegible]

[illegible]

ancestor [illegible] before the appearance of the [illegible], and that both are [illegible] descended from some Peripatus-like stem."

This view would place the [illegible] and Peripatus as distantly [illegible]

[illegible]

It may be well to consider here the structure and homologies of [illegible]

[illegible]

[illegible] they are of the nature of coxal glands, and that the ventral vesicle of the Collembola is of the same nature, with the addition of a secretory [illegible]. The sacs have retractor muscles and can thus be drawn [illegible]

[illegible] with a reduction of the sacs he regards these last as [illegible].

The first pair of abdominal appendages of insect embryos he regards [illegible]

[illegible]

[illegible]

[illegible]

Diplopoda and Peripatus.

A more generalised view of the subject has been taken by [illegible], who believes that all Arthropoda have structures homologous with these ones. The organs which he regards as homologous are: in Peripatus, the spinning slime glands and the crural glands: in the [illegible]

[illegible]

[illegible]

The relations of the groups already considered to the Arachnida must now be discussed.

The most marked similarities are the presence of tracheae or of lung-books, and of Malpighian tubes in all these groups.

[illegible]

[illegible] by means of lung-books as is seen in the Scorpions. In the Spiders lung-books and tracheae may co-exist, while in the Mites only tracheae are present (Schimkewitsch '84). The origin of the [illegible] [illegible] has been corroborated by the observations of Bruce ('87) and [illegible] of Arachnida are but modifications of the pulmonary [illegible] lung-books existing in some of the group." Without [illegible] [illegible] Kingsley ('85) as expressing the recent views upon the subject.

2. When the respiratory organs of the Arachnida are deri[illegible]

[illegible]

as evidence of the excretion. Interesting as it does, the observations of those who have examined the Malpighian tubes in [illegible] and for the present the tubes may be regarded as proctodeal and therefore ectoblastic in origin. In the Arachnids these organs have been shown by [illegible] If in Insects they empty into the proctodaeum, we have here as with the tracheae, a case of analogy rather than of homology.

Another point of difference between the Insects and Arachnids [illegible] the lack of antennae in the latter group where all the appendages appear to be primitively post-oral, while the antennae of Insects are primitively preoral.

These and other considerations which cannot here be enumerated, lead to the belief that the Arachnids have no close relationship with either the [illegible] or Insects.

One group of Arthropods remains to be considered — the Crustacea.

The old opinion that all Arthropods belonged to a common phylum has of late years wavered before a growing doubt as

[illegible] the [illegible] [illegible]. The [illegible] the [illegible] [illegible] [illegible] with [illegible] segments as its ancestors, while the [illegible] [illegible]

[illegible]

[illegible]

[illegible] Peripatus as we have seen, does not agree well with either group in its development nor in some of its adult features. The Crustacea differ from all of these groups in a number of [illegible]. Thus the proctodaeal excretory tubes of the Hexapoda and [illegible] are [illegible] [illegible] here, the [illegible]

[illegible]

shell glands. The appendages of the Crustacea are typically biramous, while they are never so with a few doubtful [illegible] in the other groups. In the Crustacea the proctodaeum is

[illegible]

[illegible]

embryological characters also exist, which indicate a separation of the Crustacea from all the Tracheata except the Arachnida.

While great differences between the Crustacea and Arachnida [illegible] [illegible] [illegible] less [illegible] [illegible] than of these and the others. In the Arachnida all the

[illegible] seem to be [illegible] in [illegible] and [illegible]

of the Crustacea, at least as far forward as to include the second

[illegible]

[illegible]

which have already been shown to be an involuted appendage and

[illegible]

[illegible]

the Arachnida, corresponds with the presence of similar [illegible]

described by Spencer ('85) as occurring in the mesenteron of

[illegible]

[illegible]

[illegible]

[illegible] Eisig's view however, would lead to these glands being

[illegible] as a general arthropodan character, and therefore as of

[illegible]

These and the facts previously presented render a discussion

of Haeckel's Zoëa Theory unnecessary, and a common ancestor of all

these groups must certainly have lived at a period long before the

[illegible]

[illegible]

[illegible] the most recent view as to the relations of the different groups of Arthropods may be expressed as follows. "The primitive Arthropod trunk near its root divided into two great branches of which one developed through the Phyllopoda forming the Crustacea and early giving off a branch which developed Limulus and the Arachnida. The other great branch, through Myriapod-like forms, developed the Hexapoda."

The weakest portion of this view is its assumption of the development of the Hexapoda through Myriapod-like forms, and those who dissent from this view, while accepting the relation of the Crustacea and Arachnida as given above look upon the Myriapods [illegible] the Myriapodan [illegible].

We now confront the question — what is the origin of the Arthropods? [illegible] have been made to answer this question. Assuming the monophyletic origin of the entire subkingdom, the most primitive [illegible] aid in the solution of the problem. Embryology has also been

called on to give assistance for the value of ontogeny as a recapitulation of phylogeny, analogical only though it may be, is universally recognized. In larval stages where the animal is [illegible] ancestral [illegible] modified or concealed by secondary ones, since larval stages which are ancestral can only persist in an unchanged environment. As these changes have been far greater on land than in the ocean, it follows that marine larvae show more trustworthy features for phylogenetic study, than do terrestrial ones, and this explains the importance of determining the ancestral Crustacean, for the light it should throw upon the derivation of the entire group of Arthropoda.

The general presence of a zoea larva in the developmental stages of the Malacostraca, for a time led to the belief that this larva represented an ancestral stage in the history of this group. More complete and accurate observations [illegible] which had been classed as zoeas being in reality quite different and heterogeneous in different Crustacea. These observations also called attention to the fact that in many cases a simpler larva was present, appearing before the zoea in ontogeny, and differing from the latter in that it could be clearly distinguished from other larval forms even in widely differing Crustacea. As a result

of these observations the zoea is no longer regarded as ancestral but has been relegated to the class of secondary larvae.

The significance of the protozoea is a distinct question. Its slight variability in different forms however and other reasons have led to its acceptance as an ancestral form, but not the most ancestral form [illegible] [illegible] [illegible] the egg is not a protozoea but a simpler form — a true Nauplius comparable in all respects with the Nauplius larva of the Entomostraca. This Nauplius having the same characters, whether as a larval Decapod Cirriped, Phyllopod or Copepod is generally accepted as representing the most ancestral stage [illegible] [illegible] the stages [illegible] [illegible] of the larva [illegible]

The [illegible] [illegible] [illegible] diverged from this Nauplius ancestor. [illegible] Malacostraca were derived from some stage subsequent to the Nauplius,

which he designates as the [illegible], and regards the [illegible] as being the [illegible] representative of that form. This view would explain [illegible] as an ancestral feature common to both branches. The Nauplius is therefore, regarded as representing (with a few secondary modifications) the [illegible].

[illegible] objections to this view. He claimed that the ventral nerve chain of the Annelids, Crustacea and Tracheata was homologous, and that any phylogenetic view which conflicted with this was untenable.

[illegible] the Nauplius represent an ancestral [illegible] has no ventral chain, this must be a more recent development. But as the Annelids cannot have been derived from the Crustacea since the Nauplius, it follows that the ventral chain in Annelids has been independently acquired, from that of the Crustacea. But as the first statement was that the ventral chain is homologous, the Crustacea must be derived from the Annelids, and the Nauplius is secondary. "Zweifellos hatte die Stammform der jetzt lebenden Crustaceen die Naupliusform ein ontogenetische [illegible] zu durchlaufen."

Since the publication of this [illegible] quite a number of [illegible] workers have become inclined to look upon the Nauplius as a secondary non-ancestral form. One of the most active opponents of the Nauplius theory is Lang who in his Textbook of Comparative Anatomy [illegible] gives

[illegible]

as General and Special. The general grounds for the rejection of the Nauplius theory are: 1. We know of no animal which in its adult condition is comparable to a Nauplius. 2. We

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] single exception, open on portions of the body which in the

[illegible].

If on the other hand, we regard the Nauplius as a characteristic larval, but not ancestral form for Crustacea, it is easily explained by the assumption of an annelid-like ancestral form for the group.

Just as the ancestral form of the Crustacea leads back to the Annelids, so the larval Crustacean leads back to the larval Annelid. Characters of the adult appear earlier and earlier in development. Thus in the Crustacean larva which corresponds to the Annelid trochophore Crustacean characters have appeared; viz. the three pairs of legs and the dorsal shield. The new mode of locomotion, by legs, has rendered [illegible] mode useless and the ciliated rings of the trochophore are therefore [illegible]

become the three most anterior pairs of the adult. Why is it that these three pairs and only these appear? The answer is, that in a young larva escaping from the egg at a very early period, as is the case with [illegible] essential to an independent life and the obtaining of nourishment.

These three pairs of appendages serve for locomotion, and also in part [illegible] which they are situated. When the egg has more food yolk the larva escapes as a [illegible] with the foundations (anlagen) of other appendages.

[illegible]

[illegible]

the [illegible] one, the [illegible] [illegible] [illegible] [illegible] [illegible] the [illegible]

[illegible] [illegible] [illegible] [illegible]."

In conclusion, Lang says: "Der Nauplius ist also auf eine [illegible] [illegible] [illegible] [illegible] [illegible] zurückverweist sind, sie ist ungegliedert, enthält die Anlagen der vorderen Kopfstücke der erwachsenen Krebse mit dem Munde und die [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] Weiterentwickelung der Larve sich der übrige Körper ansetzt und wie bei den Anneliden von vorn nach differenzirt. Der Nauplius ist eine typische Krebslarve; die Vorfahren der Krebse besassen noch keine typische Naupliuslarve, noch weniger stammen sie von einem naupliusähnlichen Stammform ab."

These conflicting views may now be compared [illegible] tested by such evidence as can be obtained from the [illegible] [illegible]. [illegible] in Insects, the conclusion reached was [illegible] [illegible] to have been derived from an ancestor with [illegible] [illegible] segments, for reduction rather than increase of the number [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] [illegible] while Peripatus throws no light whatever upon this point.

In the Arachnida concentration also apparently occurs.

The general resemblance of the adult Peripatus to [illegible] [illegible]

[illegible]

[illegible]

reason for placing the Arthropoda to the Annelida however, is the structure of the [illegible]. [illegible] the Arthropods are animals made up

[illegible]

[illegible]

[illegible]

[illegible] Annelida [illegible]

[illegible]

[illegible]

[illegible]

regard the Arthropoda as descended from an Annelid stock, and reject the Nauplius larva of Crustacea as being only secondary.

Others reject the Annelid theory at least [illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible] Insecta, Myriapoda, [illegible] Trilobites and Insects are [illegible].

Without commencing this line of thought further here, we come to the consideration of certain features which may aid in phylogenetic speculation. The Tracheae, not being present in any group simpler than the Arthropoda, as tracheae, must be modifications of organs having some other function in the ancestors of the Tracheata, as it is inconceivable that rudiments of tracheae should be of sufficient value for respiratory purposes to their possessors that they should be preserved. Regarding the Tracheata as [illegible]

[illegible]

This view has been negatived by the discovery that the nephridia are derived from the mesoblast while the tracheae are epiblastic, and by the coexistence of nephridia and tracheae in Peripatus. Moseley has suggested that the tracheae are homologous with the cutaneous glands of Hirudinea [illegible]

[illegible]

[illegible] etc., [illegible] in a [illegible] animal and [illegible] become more complicated and [illegible] as the other [illegible] become more complicated and folded."

If as has been indicated above the tracheae of the Arachnids have arisen as modifications of the lung books, they must either have originated independently from those of the other Tracheates or those groups are derived from the Arachnids, the reverse—that the Arachnids are derived from the other Tracheates—being disproved by their Crustacean affinities and in other ways. The derivation of the other Tracheates from the Arachnids cannot be accepted either. Then in Arachnids and Diplopods the stigmata open on the ventral plates; in the Hexapods and Chilopods outside these plates, and in Peripatus they are scattered over the entire surface of the body. These differences [illegible] distribution may indicate an independent origin of the tracheae in the different groups. Emery suggests (Brasil, '86. Am. Nat. review) that if the tracheae have arisen from diffused [illegible] openings might be supposed to unite [illegible] then gain a segmental arrangement.

The origin of the Malpighian tubes has also attracted considerable attention. One view—that they are homologous with the

[illegible] — has already been stated [illegible] in the [illegible] nephridia but this view has recently been rather laid aside.

Beddard ('92) however has recently described in [illegible] Acanthodrilus

[illegible]

continuous with tubes lying in the nephridial network and not distinguishable from the nephridia. To change these to ordinary Malpighian tubes Beddard states that it would only be necessary to limit their number and arrange them regularly. Their absence in Peripatus would be explained by the assumption that this secondary relation had not been established in that group.

The presence of similar tubes derived from the hypoblast and from the epiblast is a difficulty, however, and leads to a suspicion that these excretory tubes may have been independent developments with no true homology existing between them.

[illegible]

From an examination of the skin and ectodermal glands of the [illegible] he believes that from the spinning glands of Annelids have developed the Annelid bristle glands, and the different [illegible] structures enumerated above as being considered homologous by him.

Following [illegible] article in [illegible] ('9[illegible]) on the [illegible] of [illegible]

In a note in [illegible] on the homologies of [illegible]
he concludes that the coxal glands of Limulus are the [illegible]
remnants of [illegible] [illegible] [illegible].
He also regards the green glands of Crustacea as modified nephridia,
and thinks that the segmental ducts of Arthropods would probably be
also so considered.

[illegible]

[illegible] ducts in [illegible], Peripatus, Myriapoda, Scolopendrella, [illegible],
Insects and Arachnids, and probably also the weapon glands of the
[illegible] Insects.

Conclusion.

The tendency of Morphology at the present time seems to be to seek for universal homologies, oblivious of the principle found by Darwin, [illegible] Variation. The argument of Patschek given above, is an illustration of this tendency. Darwin in his Origin of Species says under this heading: "The members of the same class, though only distantly allied, have inherited so much in common in their constitution, that they are apt to vary under similar exciting causes in a similar manner; and this would obviously aid in the acquirement through natural selection of parts or organs strikingly like each other, independently of their direct inheritance from a common progenitor."

The great differences of opinion as to the origin and relationships of the Arthropoda may perhaps become reconciled through this view, and homologies no longer be sought for between structures which are only analogous.

If in some [illegible] the resulting branches might remain under nearly the same conditions and [illegible]

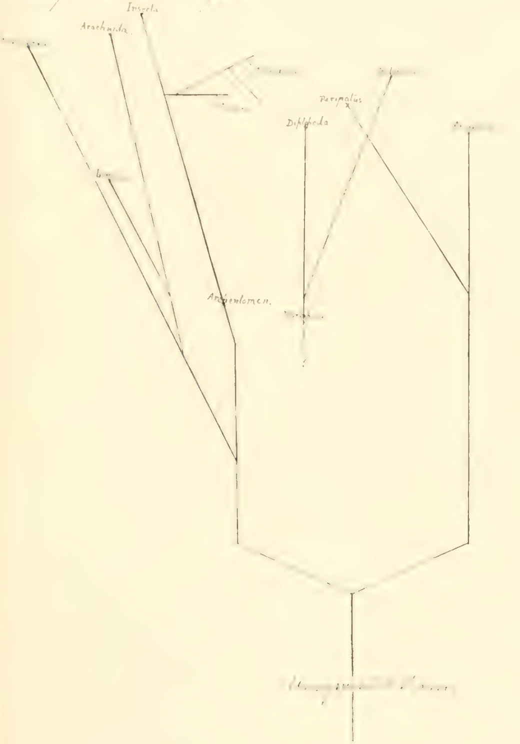
environment occurred affecting these branches in the same manner and degree, the most favorable variations ensuing would tend to be preserved, and these would probably be almost the same in the different branches. In this way might independently be developed the segmentation of the body, the general structure of the nerve chain and other features common to Annelids and Arthropods. If now, changes of environment should occur, differing between the groups, this would result in the appearance of different variations, in the groups, of which those most nearly alike would perhaps no longer be most beneficial to all the groups; and in consequence different variations would be preserved by natural selection. These divergent features [illegible] frequent further changes of environment would be followed by a rapid divergence of the groups.

This view has little or no direct evidence in its favor, but in the search for homologies it should not be forgotten that such an analogy is at least conceivable and if not so far-reaching as here hypothetically assumed, it may at least explain some of the less important similarities.

If this hypothesis were to be fully accepted, the relations of the groups concerned, would perhaps be that expressed in [illegible]

... divergent groups with increasing complexity; horizontal lines little variation; and descending lines a degradation.

The branches of the Insecta, Arachnida and [illegible] have not been developed in the diagram.



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Explanation of Plates.

Common Letters

abd. app. — Abdominal appendage

al. m. — Alar muscle.

an. — Anus.

ant. n. — Antennal nerve

ao. — Aorta

b. c. — Buccal cavity.

b. m. — Basement membrane, tunica propria

b. n. — Buccal nerve.

bl. c. — Blood corpuscle

bl. s. — Blood sinus.

br. — Brain.

cal. — Calyx

c. c. — Crystalline cone

c. m. — Circular muscle

co. — Cornea.

cor. — Corneagen

c. n.	Cell [illegible]
c. t.	Connective Tissue
cu.	Cuticle
cut.	Cuticula
d. b.	Dark band.
d. m.	Dilator muscle of the Pharynx.
e. d.	Ejaculatory duct.
ep.	Epithelium.
ex.	External limiting membrane
f. g.	Fore Gut.
g. c.	Ganglion cell.
g. r.	Germinal ridge.
h.	Heart.
h. g.	Hind Gut.
hs	[illegible]
hy.	Hypodermis.
k. m.	Krause's Membrane
l. b.	Light band.
l. m.	Longitudinal muscle
m.	Muscle fibre

These figures were drawn with a Zeiss-Oberhaüser camera and a No. 7 eyepiece. The Zeiss objective used is stated for each below. The drawings have been made with a view to a reduction of one third by the process for their transfer to stone, but the reduction has been nearly one half.

Figures 1 to 63, inclusive, are of Anurida maritima: the remainder are of Lepisma saccharina.

Fig. 1. Surface view of the cuticula showing the [illegible] which cover it. D.

Fig. 2. Section of the hypodermis and cuticula with a faint division of the latter into two layers, indicated. D.

Fig. 3. Vertical, slightly oblique section of the anterior part of the head. The jaws are cut just behind their tips, and the pharynx is cut almost tangentially. Slightly diagramatic. C.

Fig. 4. Longitudinal section of the oesophagus. D.

Fig. 5. Cross section of the oesophagus showing the epithelial ridges. D.

Fig. 6. Attachment of two muscles to the body wall showing the modification of the [illegible] at that point. D.

Fig. 7. Portion of the fat body. D.

Fig. 8. Muscle of a leg showing light and dim bands and Krause's membrane. D.

Fig. 9. Maxilla showing its division at the tip into three portions. D.

Fig. 10. Mandible. D.

Fig. 11. Surface view of the Mid Gut showing the relations of the different muscle fibres and epithelium. D.

Fig. 12. Longitudinal section of the valve between the oesophagus and Mid Gut. D.

Fig. 13. Cross section of the same. Larger specimen. D.

Fig. 14. Cross section of the Mid Gut in the mesothoracic region. [illegible] the body. D.

Fig. 15. Cross section of the Mid Gut in the third abdominal segment. Same specimen as last. D.

Fig. 16. Longitudinal section of the entire Hind Gut and of the valve between it and the Mid Gut. D.

Fig. 17. Cross section of the Hind Gut. Slightly diagramatic. D.

Fig. 18. Longitudinal section of the posterior end of the heart [illegible]

Fig. 19. Cross section of the heart close to a pair of ostia which show plainly through the walls. 1/12 inch immersion lens.

Figs. 20–27. A series of outlines drawn by camera showing the relations of the heart and aorta to the digestive tract. Fig. 20, in the metathorax; Fig. 21, in the mesothorax; Fig. 22, in the prothorax, at the valve between the Fore and Mid Guts; the heart has now become the aorta; Fig. 23, just in front of the prothoracic pair of legs; Fig. 24, at the front of the prothorax; Fig. 25, at the back part of the head; Fig. 26, a little farther forward; Fig. 27, just posterior to the brain. C.

Fig. 28. Blood corpuscles. D.

Fig. 29. Glandular cells situated in the dorsal and posterior portions of the head. D.

Fig. 30. Duct leading from these cells, on each side, to the mouth. D.

Fig. 31. Opening of this duct upon the ventral external surface of the lower lip at the posterior end of the median cleft. The section drawn was not quite exactly longitudinal and hence this cleft is not seen. 1/12 inch immersion lens.

Fig. 32. Cross section of the ventral tube leading from the foramen shown in Fig. 31 to the abdominal vesicle, the section taken in the region of the head. D.

Fig. 33. Cross section of the same in the mesothorax. D.

Fig. 34. Cross section of the abdominal vesicle. The cells have [illegible]

Fig. 35. Cross section vertical of the brain, cutting the optic lobes and the ocellar nerves leading from the optic lobe to the ocelli two of which are also cut; and showing the relative position of the brain and oesophagus. D.

Fig. 36. Cross section of the brain in front of the optic lobes. D.

Fig. 37. Longitudinal section (vertical) of the brain, on one side of the median line, cutting the root of the antennal nerve. D.

Fig. 38. Longitudinal section of a dorsal ganglion. D.

Fig. 39. Cross section of the metathoracic ganglion showing the nerves leading to the metathoracic pair of feet. D.

Fig. 40. Surface view of the metathoracic ganglion from above, with its main nerve trunks. D.

Fig. 41. Surface view of part of the left side of the upper surface of the head, showing the post-antennal organ and the ocelli in their relative positions. D.

Fig. 42. Vertical section of an ocellus. 1/12 inch immersion lens.

Fig. 43. Vertical section of a post-antennal organ. The pigmented tissue [illegible] D.

Fig. 44. Surface view of a post-antennal organ. D.

Fig. 45. Section of the ventral portion of the fourth abdominal segment, showing the posterior nerve cord and two muscles supposed to represent the rudiments of the spring. D.

Fig. 46. Left antenna, showing sense bristles and a sense organ. C.

Fig. 47. Section of the tip of an antenna. The hypodermis is shrunken away from the cuticula but without breaking the nerves running to a sensory bristle and to the sense organ. D.

Fig. 48. Camera outline, showing the form of the sense organs. The dotted line is seen on focusing deeper. D.

Fig. 49. Cross section of the testis of an immature male. D.

Fig. 50. Cross section [illegible] line A.B. Fig. 5[illegible]. D.

Fig. 51. Longitudinal section of the vas deferens and [illegible] D.

Fig. 52. Cross section of the vas deferens. D.

Fig. 53. Longitudinal section, somewhat tangential, of the vagina, oviduct, receptaculum seminis and a portion of [illegible] D.

Fig. 54. Cross section of the oviduct and receptaculum seminis. D.

Fig. 55. Cross section of the ovarian tube showing strings of germinal cells. Young female. D.

Fig. 56. Longitudinal section of the anterior end of an ovarian tube, showing germinal epithelium. D.

Fig. 57. Longitudinal section of part of an adult ovarian tube showing maturing ova. D.

Fig. 58. Longitudinal section of the testis showing the changes in the maturation of spermatozoa from the condition shown in Fig. 50 to the adult, showing seminal globules. D.

Figs. 59–62. Cross sections of a testis, maturing spermatozoa:

Fig. 59, represents a stage intermediate between Figs. 47 and 58; Fig. 60, a cross section along the line C.D. of Fig. 58; Fig. 61, a cross section along the line E.F. of Fig. 58 and Fig. 62, a cross section along the line G.H. of Fig. 58. D.

Fig. [illegible] Longitudinal section of the vas deferens of an adult male. D.

" [illegible] seen from the [illegible] surface [illegible]

" [illegible] Scale [illegible]. D.

" [illegible] Section of hypodermis and cuticula showing attachment of setae. D.

" [illegible] Section of cuticula and hypodermis at the junction of the prothorax and mesothorax on the dorsal surface, with a muscle attachment. D.

" [illegible] Cross section of a bundle of muscle fibres. 4.

" [illegible] [illegible]. 4

" [illegible] [illegible]

" [illegible] [illegible]

" [illegible] Cross section of the pharynx. C.

" [illegible] Cross section [illegible]

" [illegible] Cross section [illegible] Malpighian tube in section, just external to it. [illegible]

[illegible]

" [illegible] Cross section of the ileum with [illegible] of its [illegible]. [illegible]

Fig. [illegible] [illegible]

[illegible] D.

Fig. [illegible] Longitudinal section of a Malpighian tube, showing the yellowish granules. D.

Fig. [illegible] [illegible]

[illegible] D.

Fig. [illegible] Cross section of the heart in the posterior region of the abdomen. D.

Fig. 50. Cross section of the heart, in the metathorax, showing blood corpuscles, and nuclei of the muscles of the walls. D.

Fig. 51. Longitudinal section of the metathoracic and first two abdominal nerve ganglia. A.

Fig. 52. [illegible] the nerve cord, showing the sixth, seventh and eighth abdominal ganglia. After Grassi ('87a.)

Fig. 53. Cross section vertical of the protocerebrum, showing the antennal nerve, and the calyx and cutting the anterior edge of the optic lobe. C.

Fig. 54. [illegible] eye. One ommatidium has been depigmented; the other

is left with the pigment in place.

Fig. 85. Diagram of the parts of an ommatidium separated from its main axis and projected onto a plane, the more superficial layers being external to the deeper layers. Two of the cells of the retinulae have pigment; it is removed from all the other cells.

Fig. 86. Diagram of the anatomy of the adult [illegible]. After Grassi (57a).

Fig. 87. Diagram of the anatomy of the [illegible] [illegible]. After Grassi (57a).

Henry Torsey Fernald was born in Litchfield, Maine, April 17, 1866. He prepared for college [illegible] and entered the Maine State College in 1881. His course there included French, German, algebra, geometry, trigonometry, surveying, botany, zoology, [illegible] chemistry, physics, logic, ethics, political economy, and other studies. He graduated in June, 1885, receiving the degree of B. S. In June 1888, on presentation of a thesis and drawings he received the degree of M. S. After graduation he devoted a year to studies in Biology at Wesleyan University, Middletown, Conn. In the fall of 1886 he entered the Johns Hopkins University as a student in Biology but was obliged by ill health [illegible] the Chesapeake Zoological Laboratory to Nassau, N. P., Bahama Islands, and in the fall of the same year resumed his studies at the Johns Hopkins University.

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